Vol. 36. No. 214 AUGUST, 1947 Price 2/- [Subscription 24/- per annum, post free]

METALLURGIA

THE BRITISH JOURNAL OF METALS

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The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER)

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PRINCIPAL CONTENTS IN THIS ISSUE:

Subscription Rates throughout the World - - 24/- per annum, Post free

Published monthly by THE KENNEDY PRESS, LIMITED.

REGISTERED OFFICE: 31, King Street West, Manchester, 3. *Telephone:* BLA 2084. *Telegrams:* "Kenpred," Manchester.

LONDON OFFICE: Bedford Street, W.C. 2. *Telephone:* Temple Bar 2629.

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Into Battle

THE results of the recent economic debate in the House of Commons have left the majority of us with a feeling of depression. We have been told, at considerable length, that the nation's accumulated wealth was practically exhausted to win the war and that the loan we obtained from the United States, to help us to re-establish our trade lost because of the war, will be exhausted in about three months unless something very drastic is done. It seemed that the stage was set for a lead of great magnitude which would have thrilled the House into a sense of duty and responsibility that would have vibrated throughout the country. But no such lead was given, and a really great opportunity was lost.

We are spending about £600 million more than we are earning, and import cuts are to be made which will save about £200 million, about a third of the way towards closing the gap, and, without any clear plan, the Government is relying on a rapid expansion of exports to close still further this gap. The difference between our expenditure and income has been met by loans, largely from the United States loan which is being exhausted faster than was anticipated when the loan was effected, because prices of essential foodstuffs and raw materials have increased.

Many appreciate the position and realise that an economic crisis will be upon us shortly and that to combat it the whole nation must be keyed up to regard it as a turning point in our history, either for good or ill. We are justified in expecting a demonstration of the Government's capacity to guide the nation through this economic blizzard. To do this the Government must take much more imaginative steps to create in the nation a sense of urgency and realism about our economics survival. Public morale is not geared up to the size or pace of the job and needs the impact of bold, concerted, inspired leadership.

What are these qualities of leadership, which the war proved unmistakably to be of first importance and which is true of every decision that requires to be taken in the essential interests and security of the nation? It is no more possible to define them than to define the qualities of an artist. It has been said that great leaders are born not made; undoubtedly, however, training to provide the necessary background would be essential to develop the best in the potential leader. Certainly those responsible for directing industry pit their organising, productive and commercial ability against contemporary competition from wherever it may come, and, according to the degree of enterprise and leadership displayed in each unit of industry, efficiency, in the end, outstrips inefficiency.

Is this heresy in these post-war days? We are still old-fashioned enough to believe that organisation and leadership are the nerve centres of industry; competition their activating force. Without them no industry can survive. And, although the worlds markets are starved for products we can supply, we shall experience the effects as competition for markets becomes more acute. Leadership is a virtue of industry and the real driving force behind all organisation; it demands the energy, will and enthusiasm to develop every material resource, actual or potential. In total war, necessity demands production on an unprecedented scale with an increased scale of output, and experience has shown that peace-time standards and practices of industrial management, direction, leadership and outlook completely fail to drive the machinery of production at that overload speed and capacity which emergency conditions demand. In these circumstances, only leadership and direction of the highest calibre will successfully push production towards peak level and succeed, by an unswerving degree of control, in maintaining it there.

Conditions of emergency exist to-day, and if we are to alleviate the economic crisis, let the Government give some unmistakable indication of the task before us, what failure to bridge the gap in our overseas payments will mean in terms of our standard of life. We would then know what had to be done and the price of our failure to do it. But in making such a statement it should be coupled with a call to action of such a character as to inspire all to gird themselves for the battle, "spivs" included—and there are many "passengers" in workshops to whom this term could be applied. Certainly, unless greater production is achieved, the future of this country is, indeed, a grim one, and would react on the Government's efforts to improve general educational facilities, raise the standard of living, help the sick and aged, reduce working hours and bring about better working conditions, which can only be supported by earnings. In an emergency of such a momentous character, restrictive practices, encountered in works, designed to prevent exploitation and to safeguard employment, would obviously cease. Penalties for working hard are just plain lunacy in these times, under a full employment policy, and the only moral objection to measured output should be that the measurement is unjust or inapplicable. And it would be fatal to allow the dead hand of bureaucracy to muddle and waste efficient efforts of experienced industrial leaders proved to be of the highest calibre.

Above all it must be made clear to all that there is no short cut to economic security for the country. Austerity will long remain with us as there are no means of effecting a rapid solution to the problems that beset us. Persistent hard work is the best that can be done and, under adequate leadership, the same degree of skill, energy and resourcefulness, that served us so well during the war years, are still available and could be applied, if not to prevent the crisis, to substantially reduce its effect and to restore confidence in Britain's ability to overcome her adversities.

Colleges of Technology and Technical Manpower

THE Barlow Committee in its Report on Scientific Man Power (Cmd. 6824) stated (para. 2) that "if we are to maintain our position in the world and restore and improve our standard of living, we have no alternative but to strive for that scientific achievement without which our trade will wither, our Colonial Empire remain undeveloped and our lives and freedom will be at the mercy of a potential aggressor." Doubling the number of scientists (para. 24) and of technologists (para. 34) is a matter of the utmost urgency. This task will fall upon the Universities and the major technical colleges.

The position, so far as the Universities are concerned, has been the subject of a report entitled, "Universities and the Increase of Scientific Manpower" which was published by the Parliamentary and Scientific Committee in December, 1946. In that report (para. 9) it was agreed to issue a complementary report dealing with the major technical colleges (colleges of technology) in relation to the problem of scientific and technological man-power in this country.

At this stage, it is essential to give a definition of what is meant by the term, major technical college. In this country, technical colleges vary from small institutions undertaking comparatively elementary work to those technical colleges which have developed technological courses of a standard comparable with that of University degree courses, and in addition conduct a substantial amount of research work. The term, major technical college is in this Report strictly limited to those colleges which have already, or will have as a result of developments envisaged in the Percy Committee Report on "Higher Technological Education," technological courses equivalent in standard to university degree courses. In order to avoid confusion in this report the major technical colleges will be referred to as Colleges of Technology. Some 27 Colleges—of which 10 are in the London area—provide full-time higher technological courses of as much as three years' duration for a substantial number of students (Percy Committee Report, para. 14), but other colleges will also be raised to this standard as a result of the present development of technological educational facilities.

Mr. M. P. Price, M.P., Chairman of the Parliamentary and Scientific Committee, recently submitted on behalf of that Committee to the Lord President of the Council and the Minister of Education a report on Colleges of Technology and Technical Manpower which has just been adopted by the Parliamentary and Scientific Committee. This Report was subsequently adopted by the Parliamentary and Scientific Committee (which comprises representatives of 70 scientific organisations and some 200 M.Ps. and Peers of all Parties) subject to dissent on some points on the part of representatives of the Institute of Physics.

A summary of some of the recommendations is given below :—

To restore and enhance our industrial position and to attain full employment and an improved standard of life, it is essential to ensure that scientific and technical research is not only carried out as widely and as intensively as possible, but is applied promptly to production. For this purpose there must be an adequate output of qualified scientists and technologists which has been estimated to be at least double the present output. The major technical colleges (Colleges of Technology) could make a substantial contribution of some 5,000 to 7,000 qualified technologists and scientists a year by providing, if not already doing so, courses in technology of a standard equivalent to that attained in university courses.

Effectively to use this potential capacity for the training of qualified technologists and scientists and to attract a fair proportion of students of high ability to the courses in the colleges of technology, it is essential that a qualification should be available which has both national and international currency. In general, the only qualification which fulfils this condition is the bachelor degree. Furthermore, a bachelor degree is the only qualification from which a successful student may proceed to higher degrees.

For certain industries of great importance but requiring only a relatively small number of technologists, National Colleges with adequate equipment should be developed with the utmost speed by the Minister of Education in co-operation with the respective industries. Research in colleges of technology, and also the training of post-graduate technologists in research methods, should receive every encouragement. In general, the research should be applied in character and done in collaboration with the industry and its research association. Only in exceptional circumstances should research of a secret character for a specific firm form part of the work of a college of technology.

To maintain the standard of work, and to secure the employment of the highly qualified staff the Minister of Education desires to see in the colleges of technology, the Minister should invite the Burnham Committee to make provisions for special scales of salaries applicable to the staffs of the selected departments of colleges of technology comparable with those for staffs of universities. A head of a department (or professor) might, for instance, be paid a minimum basic annual salary of £1,400 ; a senior assistant (or reader). £800 to £1,200 ; a lecturer, £400 to £850, with appropriate family allowances.

The Governing Bodies of the colleges of technology should be given reasonable freedom in directing the affairs of the colleges and in incurring expenditure within the estimates submitted to and approved by the providing authority. The Governing Bodies must be influential and fully representative of the industries tor which the college provides training.

Engineering and Marine Exhibition

ELSEWHERE in this issue is given a very brief pre-review of some of the exhibits of the above Exhibition to be held at Olympia, London, from August 28th to September 13th inclusive, 1947. We shall be represented on Stand g, section 10, gallery, Grand Hall, where members of the staff will be available to indicate the services given to both advertisers and readers. Special copies of this journal will be available and reprints of many interesting and informative technical papers and articles which have been published in this journal from time to time, will also be available.

A New Mechanised Forge

Modern Practice in the Production of Forgings from Special Steels

An interesting example is given of modern practice in the progression of special steels from ingots in the stock-yard to finished forgings, based on the use of mechanised equipment of a new type installed at the Sheffield works of Daniel Doncaster & Co., Ltd. The materials forged are those used for hot dies, high-speed steel cutting tools and steels of the stainless and austenitic types.

Part of ingot stockyard, showing mobile manipulator taking ingot for charging into furnaces. Note the injector-type venturi stack to furnaces.

ESTABLISHED in 1778 the firm of Daniel Doncaster & Sons, Ltd. continues an uninterrupted family tradition, several direct descendants of the first Daniel Doncaster being actively engaged in the present management. The work of this firm is primarily concerned with hammer forging all class of steel—especially alloy steels—the production of drop forgings and valve forgings, and of hardened steel rolls for cold-rolling operations. In keeping with its progressive outlook, the firm recently laid down a new forge on vacant land adjacent to the main works, and it has been equipped for fully mechanised production.

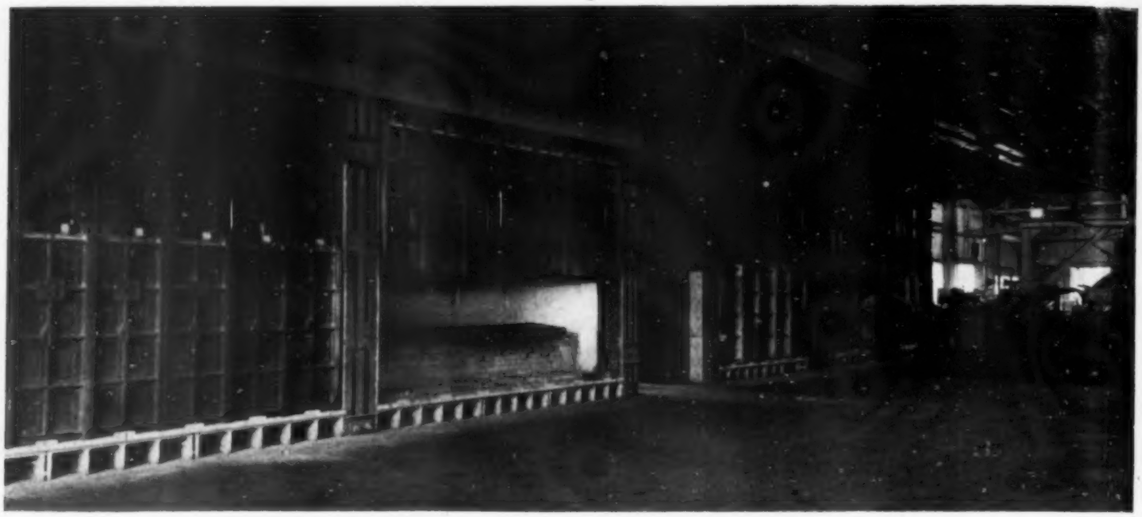
The main objective in planning the layout was the provision of the most modern methods of control for the satisfactory forging manipulation under a steam hammer of high-grade steel ingots, and in improving the working conditions of the men to minimise the effects of fatigue. The chief features in the design of this forge lie in the provision of unusually spacious buildings with a well laid blue brick floor, in the design of the hammer foundation, and in the design of the furnaces. An important innovation is the provision of a mobile manipulator to undertake all furnace charging of the material, the turning of ingots in the furnace, and the manipulation of the ingots under the hammer. Using this manipulator not only isolates the hammer team from furnace radiation, but relieves the men from much physical exertion at the hammer itself.

The materials worked in this forge are tool steels of the semi-high-speed type, such as those used for hot dies, high-speed steels for cutting tools, and highly alloyed steels of the stainless and austenitic types. The results obtained have fully justified the layout. The notable saving in manual effort and the general improvement over conditions normally encountered in forging have enabled the men to produce greater output per shift with markedly less fatigue. The complete forge installation, with its many unique features, forms a notable addition to the resources of British steel manipulation plant, and is briefly described in the following notes.

Buildings

In the provision of a suitable building for housing the equipment, special precautions were taken to obtain the maximum comfort for all working within the department. Attention was given to the design of the building housing the 4-ton steam hammer in so far as adequate glazing was provided in such a manner that the building received the full benefit of natural daylight without the discomforts of having direct sunlight. Suitably disposed around the building at a level relative to the working position of the foregemen, are arranged a series of vertical swivelling shutters which offer pleasant ventilating effects during summer periods.

The hammer building was arranged with a volumetric capacity greater than is usually considered necessary for this type of plant with the added provision of chimney-shaft-type ventilators to the roof and louvred side sheeting. The furnace building, where it adjoins the hammer building, has been sheeted down to give a minimum working clearance in height and this has the effect of trapping fumes emitted from the furnace and preventing their admission into the forge building proper.



Furnace installation with mobile manipulator.

A chimney-shaft-type continuous ventilator is arranged in this building and is most effective in clearing hot air from around the furnaces.

Integral with the furnace building, a lean-to is arranged for housing the combustion chambers and fuel bunkers serving the ingot reheating furnace. Through the roof of the lean-to are openings with sliding covers, each corresponding with a solid fuel bunker having a capacity of approximately 4 tons of screened coal. The bunkers are charged by means of a travelling loco jib crane which also handles material from the stock-yard to the forge running on lines parallel to the lean-to. By means of a grab, coal can be picked up from a storage pit and discharged directly into the fuel bunker through the roof openings.

Steam Hammer Foundation

The design of the foundation for a steam hammer is always a problem and in this case the final design departed from all preconceived ideas of hammer foundations at these works. The firm's normal practice has been to carry the hammer anvil block on a central solid block of concrete, the bulk of the concrete being usually determined by experience, taking into account the nature of the geological strata discovered during excavation, the hammer legs being supported on separate blocks of concrete abutting to opposite sides of this concrete block. It was decided to put down a conventional central concrete block to support the anvil block, and interdisposed between the anvil block and foundation to put as usual a cushion composed of three layers of English oak, each 12-in. thick. A continuous surrounding block suitably reinforced and arranged to carry the hammer legs was then cast. Between the anvil foundation and the surrounding block from base to top a 3 in. lamination of mastic asphalt was provided. It was considered that the introduction of mastic asphalt between the anvil foundation proper and the foundation carrying the hammer legs would be beneficial from the point of view of suppressing compression waves emanating from the point of impact on the hammer anvil. Further, the base of the central foundation block was cast in a corrugated formation by building a series of small piers of granite sets, the purpose of these being to prevent the persistency of impact waves at nodal points within the foundation and thus assist in the dispersal of energy.

The foundation was taken down to a depth of 27 ft. from ground level and at this point it was considered that the block mass was sufficient. The strata encountered were made up of shaley material, and it was noticed that immediately pressure had been removed by the excavation, a serious swelling took place, resulting in a very rapid deterioration of the shale ; immediately the shale came into contact with the atmosphere it very rapidly decomposed and within 24 hours became sludge. It became imperative, therefore, to cast the foundation with all possible speed to bring a pressure to bear before creating a condition which would have been fatal to the foundation.

To ensure sound concrete from the base upwards, land drains were inserted across the floor of the excavation, discharging the water into a sump which had been carried down with the excavation and to one side. Water was pumped from this sump as it entered the excavation and a foundation of homogeneous structure was thus obtained.

Adjoining each hammer leg base is a pit 14 ft. 6 in. deep arranged to facilitate the removal of the hammer leg holding down bolts. After casting the main foundation these pits were rendered with a three-quarter inch thickness of water-repellant cement. These renderings have been inspected from time to time, as it was felt most unlikely that these would remain uncracked for long after the hammer had started up. So far not the slightest flaw in the rendering of any of the four pits has been found. After six months of 24 hours a day for five days a week, the foundation appears to be absolutely stable in every direction. A remarkable feature has been the almost entire elimination of vibrations passing through the surrounding floor. No cracks of any description have appeared in any part of the foundation. It will be realised that this foundation represented an unusual line of experiment, and there was no guarantee

that results would necessarily be borne out in practice as conceived in theory. The firm is, however, convinced that this design is so successful that it can be used as a basis for future hammer foundations.

Mobile manipulator with ingot taken for furnace and ready for forging under the steam hammer.

Furnaces

To achieve continuous production in the forging of a wide range of alloy steels from ingots of diverse dimensions it was necessary to plan and co-ordinate the flow of material from the ingot stock-yard to the hammer. One of the many problems was the development of a furnace of suitable characteristics for the controlled heating of different steels at a definite tonnage rate per hour. The complexity of the problem was increased by the wide variation in the dimensions of the ingots to be handled.

A continuous furnace would be the best medium for the efficient and economical heating of ingots of uniform size and quality, but it would be unsuitable for the simultaneous heating of ingots of differing qualities and varying dimensions requiring different temperatures. On the other hand, batch-type furnaces are suitable for the heating of ingots of diverse dimensions and qualities, but are extremely inefficient when used for alloy steels which have to be gradually raised from cold, through successive critical temperatures, to the final forging heat.

After reviewing the advantages and disadvantages of different furnaces it was clear that a new type of furnace, capable of operating on the continuous principle but with the adaptability of a batch-type furnace, was needed. Study of the metallurgical requirements in relation to the variety of steels to be heated indicated a definite need for zonal control of the furnace throughout the following ranges of temperature :—

Initial preheating	0°–600° C.
Secondary preheating and soaking	600°–1,000° C.
Final heating for forging	1,000°–1,250° C.

It was clear, however, that the dimensions of the separate zones would need careful computation in relation to both the fixed production requirements and the different rates of thermal transfer in each chamber. Furthermore, as mechanical charging and withdrawal of the ingots was essential, the furnace had to be carefully designed in relation to the dimensions and characteristics of the manipulator.

A stoker-fired quintuple-chamber furnace of unusual construction was ultimately installed.

Characteristics and Features of the Furnace

Continuity of heating with zonal control and maximum utilisation of the liberated heat energy were the main objectives in the development of the furnace. One of the many problems of design arose, however, from the need to maintain unbroken draught at every chamber whenever the doors of one or another were opened for the charging or withdrawal of ingots.

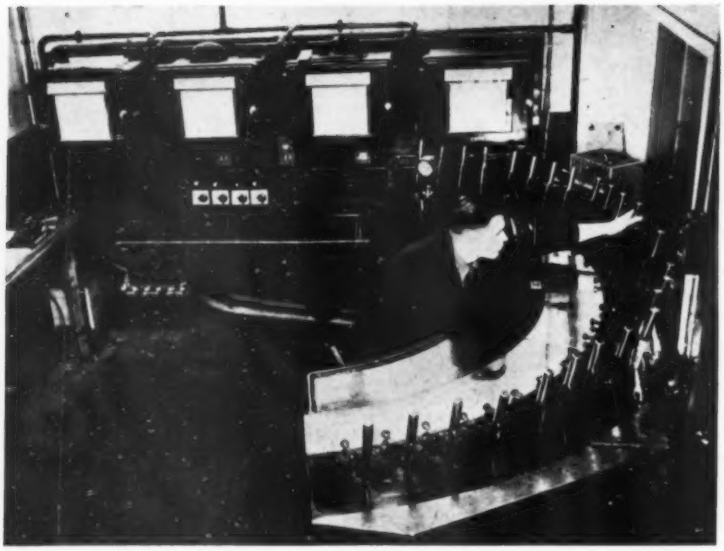
Aerodynamical consideration of the flow of gases throughout the circuit provided a solution, but the low exit temperature of the waste gases and the frictional resistances of the system necessitated the installation of an injector-type venturi stack with an external electrically-operated air-blowing fan for the creation of the draught.

Another problem arose from the characteristics of the manipulator. The lift of the furnace doors had to be adequate to accommodate the manipulator head and to allow for the raising and lowering of each ingot ; hence, consideration had to be given to the loss of radiant heat during charging and withdrawal. This was minimised by equipping the five chambers with sectional doors of the interlocking type. The opening of one section to the requisite height permits the entry of the manipulator and limits the emission of heat.

The interlocking sections have separate oil-hydraulic lifting cylinders and are operated from a central control room. The furnace is a smokeless unit with automatic regulation of the coal feed at each zone by control pyrometers of the recording type. Automatic recording pyrometric control of the furnace from atmospheric to forging temperature is installed in the control room.

The furnace, which was designed and installed by G. F. Wincott, Ltd., Sheffield, in conjunction with the firm, consists of two primary preheating chambers, one secondary preheating chamber and two tertiary heating chambers. All the chambers are in line with the forge to achieve continuity in the flow of heated material from the ingot stock-yard to the hammer.

The primary preheating chambers are combined but can be independently or simultaneously operated. They are of the semi-muffle type with hearths of heat-resisting steel each 15 ft. wide by 7 ft. 2 in. deep. Both chambers



The control desk for hydraulic opening and closing of furnace doors. Note the Kent temperature recorders.

are used for the controlled preheating of steels between 0° and 600° C. The remaining three chambers form a separate unit. The secondary preheating chamber is of the inflame type for the controlled heating of steels between 600° and 1,000° C. It is 10 ft. 9 in. wide by 7 ft. 2 in. deep. The tertiary heating chambers are also of the inflame type with hearths 6 ft. 6 in. wide by 7 ft. 2 in. deep. Both are employed for the controlled heating or reheating of steels between 1,000° and 1,250° C. The complete installation occupies a site approximately 101 ft. long by 22 ft. 6 in. wide.

The secondary preheating chamber and the tertiary heating chambers operate independently and have separate mechanical stokers of the "Unicalor" underfeed type. In each case isolated draught control is provided to ensure simple regulation of the pressure and flow conditions. The products of combustion from the three chambers are subsequently collected in a mixing flue and this waste heat is utilised in one or other of the primary preheating chambers for the under heating of the steel hearth. If desired, however, the waste heat can be simultaneously used under both hearths or short-circuited to the stack.

A single "Unicalor" mechanical stoker of the underfired type is separately fitted to the combined primary preheating chambers for the top firing of either or both, but in case of need, hot gases can be by-passed from the stoker to the flues below the hearth plates to implement the bottom heat. As a result of the unique construction of the primary preheating chambers the waste heat from the high-temperature chambers, together with the supplementary heat from the mechanical stoker can be mixed, isolated or by-passed in any desired manner thus ensuring complete control of the temperature conditions in the critical range between 0°–600° C.

Each of the four underfeed stokers is capable of feeding up to 350 lb. of coal per hour, but the feed to the worm can be varied in each machine by five different steps. The retorts are of the variety with surrounding grates, with air supply from the stoker fan partly to the tuyères and partly to the grate. The design with surrounding grate provides an increased area over which combustion can take place and ensures the rapid and complete burning of the carbonaceous residue, whilst the ash and clinker can be removed without difficulty from the air-cooled surfaces on which they are deposited.

Mobile Forging Manipulator

A feature of the forge equipment is the 4,000 lb. manipulator which handles the ingots both at the furnace and at the hammer. It is believed that this machine is the first British machine of its kind to be put to work in forging practice. Its use effects considerable economy in man-power and facilitates production, whilst greatly relieving the forgemen of heavy manual work.

The manipulator, which was designed and constructed by Wellman Smith Owen Engineering Corporation, Ltd., is mobile and capable of operating in relatively limited working space, and is operated solely by the driver. Instructions to the driver are given over a telephone system from the control room. Control is such that precise and rapid adjustments can be made to the horizontal height, and the workpiece rotated continuously as required.

Electric power is furnished to the manipulator by a flexible cable connected to an overhead cable drum mounted on a trolley-way running the full length of the shop, and allowing the machine to operate within a 30 ft. radius of the trolley track. The main driving motor is used to operate the hydraulic pump for those motions which are effected hydraulically and also the electric generator of the travel motion.

Twin electric motors drive the rear castor wheels, avoiding the need for a mechanical differential. Control of the travelling motion is provided by means of a reversible drum controller and foot-operated Lockheed hydraulic front wheel-brakes. Steering of the castor wheels is by two hydraulic cylinders controlled by hand-wheel and follow-up valve. The machine can turn in a minimum turning radius of 12 ft. when the castor wheels are rotated through 90° from the straight ahead position.

The hydraulically-operated and easily interchangeable grips, of a particularly robust construction, are capable of holding and maintaining a workpiece up to 4,000 lb. in weight and 6 ft. 6 in. in length. The grips are continuously rotatable by means of a hydraulic motor, the rotational mechanism being amply protected against shock to prevent damage to the manipulator, should the workpiece be out of square with the hammer during forging. Lowering and raising of the workpiece (hoisting motion) is done by hydraulic cylinders, the arrangement of link gear being such that the grips and workpiece always remain in a true horizontal plane irrespective of the operating height.

The operating speeds of the various motions for normal working are as follows :—

Travelling :	264 ft./min.
Grip rotation :	12 r.p.m.
Hoist raising and lowering :	15 ft./min.
Gripping :	Full range 8 secs.

The hydraulic operating pressure is 450/750 lb./sq. in.

Continued on page 222

Reactions in the Acid Side Blown Converter

By Norman F. Dufty A.I.M., A.Met.

The main advantages of the acid side-blown converter are generally known, but it is only during recent years that attention has been given to the reactions taking place in this type of converter. A considerable amount of data has been accumulated, and the author applies theoretical considerations to this data with the object of defining the nature of reactions that occur.

Introduction

THE acid side blown converter has many advantages in a small foundry making plain carbon and low alloy steel castings, the main one being that hot, fluid steel can be supplied in small quantities at frequent intervals.

Prior to 1940 very little work had been done on the reactions taking place in the converter. The First Report of the Side Blown Converter Practice Sub-Committee,[1] however, represents a really serious attempt to elucidate some of the steelmaking problems involved. A considerable amount of valuable data has been collected, and an effort will be made in this article to apply theoretical considerations to this data and to draw some conclusions as to the nature of the reactions that occur.

Normal practice is to take iron from the cupola at about 1,400° C. This is desulphurised by the soda ash process, usually in a basic ladle, and then poured into the converter after removing the alkali slag. The charge in the converter will then be somewhere in the region of 1,300° C. and will contain approximately 3% carbon, 0·4% manganese, 1·2% silicon, 0·04% sulphur and 0·04% phosphorus.

The blow can be divided into two or three stages. First of all the silicon and manganese oxidise, then the carbon and finally, if the bath is hot enough, there may be some silicon pick-up.

Oxidation of Silicon and Manganese

When the metal is poured into the converter it has little or no slag covering. As soon as the air blast impinges on the surface of the molten charge some iron, silicon and manganese are oxidised by the direct action of the atmospheric oxygen. The main reaction mechanism, however, is the formation of iron oxide at the air-metal interface and its diffusion downwards to react with the manganese and silicon in the charge. At the same time manganese and silicon will diffuse upwards from the main body of the charge towards the area immediately adjacent to the air-metal interface which has been impoverished of these elements by the action of the dissolved iron oxide. The actual reaction zone is quite close to the surface due to the high speed of diffusion of iron oxide, manganese and silicon at the temperatures involved. Assisted by the agitation set up by the air blast from the tuyeres, the reaction products rapidly rise and either pass directly into the slag or are blown into it across the face of the bare metal.

The slag is formed from the oxidised iron, silicon and manganese together with any silica added with the charge or eroded from the converter lining. Taylor and Chipman[2] have shown that iron oxide-silica slags show little or no deviation from Raoult's Law and are therefore completely dissociated into iron oxide and silica at steelmaking temperatures.

The air blast forces the slag towards the side of the converter away from the tuyeres, leaving approximately equal areas exposed to slag and air. At this stage, with appreciable quantities of silicon and manganese still in the bath and from 40–50% of iron oxide in the slag, the latter plays a definite part in the reactions. Its main function is to assist in maintaining a flow of iron oxide into the metal to oxidise the silicon and manganese. The partition coefficient, calculated from Taylor and Chipman's[2] data, is 0·0125, giving a theoretical value of 0·5% iron oxide dissolved in the bath if the latter was

1 *Journ. Iron and Steel Inst.* (1947), Vol. 155, p. 33.

2 Taylor and Chipman. *Metals Technology.* September, 1942.

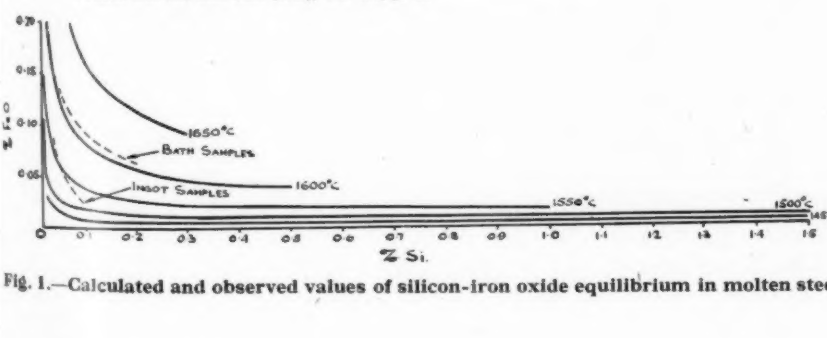
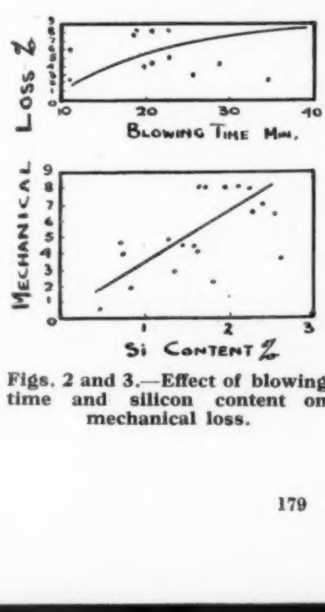


Fig. 1.—Calculated and observed values of silicon-iron oxide equilibrium in molten steel.



Figs. 2 and 3.—Effect of blowing time and silicon content on mechanical loss.

pure iron. As will be seen from Fig. 1, the iron oxide in equilibrium with more than 0·2% silicon at 1,450° C. is only 0·005%, so there is a considerable oxygen potential between slag and metal. It is probable, however, that the reaction is predominantly air-metal with iron oxide as the oxygen carrier. The only evidence in support of this is the fact that the rate of silicon and manganese oxidation is not perceptibly reduced by drastically lowering the activity of the slag by sand additions.

It is usually found that about 1·2% of silicon is needed in the charge to ensure that the bath temperature is high enough at the end of the blow. The main fuels in the converter are carbon and silicon, but the former is comparatively invariable and is dependent to a large extent on cupola design and practice. Unless the iron is preheated, adjustment of the silicon content is the only method of controlling the final temperature.

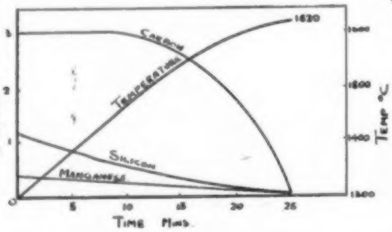


Fig. 4.—Metal composition and temperature at progressive stages of the blow.

For several reasons it is a disadvantage to have too much silicon. The chemical blowing loss will obviously increase, so will the blowing time and with it, the mechanical loss. This is amply illustrated by Figs. 2 and 3.[1]

Manganese oxidation occurs throughout, but mainly during the early part of the blow ; it has little effect on the other reactions. When more than 1% manganese is present, however, the manganese oxide produced is sufficient to lower the melting point of the slag, making it corrosive and very fluid. This naturally leads to excessive wear of the converter lining and the slag has a strong tendency to slop out of the converter.

Fig. 4 illustrates a typical blow in which the final temperature is not high enough to cause any appreciable silicon reduction. During the first 15 minutes, when most of the silicon and manganese are oxidised, there are numerous ejections from the converter ; this is known as the silicon blow. The carbon blow takes place over the remaining 10 minutes and the flame has a characteristic appearance with very few ejections.

Oxidation of Carbon

Although carbon removal commences at about 1,450° C., the carbon blow does not really start until about 1,550° C. If carbon oxidation is allowed to continue below this temperature, not only does the rate of oxidation remain low but the final bath temperature will also be too low. From Fig. 4 it can be seen that at 1,550° C. 10% of the carbon and 75% of the silicon have been eliminated. The reason why carbon removal is practically non-existent below 1,450° C. can be seen from Fig. 1 which is calculated from Darken's[3] equation :—

$$\log [Si] [FeO]^2 = -43930/T - 20 \cdot 24$$

3 Darken. *Trans. A.I.M.E.* (1940), Vol. 140, p. 217.

At this temperature the iron oxide in equilibrium with more than 0·2% silicon is only 0·005%. From Herty's figures for the carbon-iron oxide product at higher temperatures, quoted by Schenck,[4] the value at 1,450° C. can be taken as 0·015. This gives the carbon content under equilibrium conditions as 3%. A slight rise in temperature will bring the equilibrium figure for carbon below that of the charge and the carbon-iron oxide reaction may commence. At 1,550° C., even with 0·5% silicon in the metal, the dissolved iron oxide can rise to 0·02% and as the carbon-iron oxide product at this temperature is 0·013, the carbon may drop as low as 0·65%. The rate of carbon fall now depends on the rate of iron oxide formation, carbon and iron oxide diffusion and carbon monoxide removal.

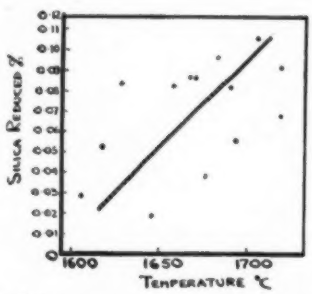


Fig. 5.—Effect of temperature on reduction of silica from the slag.

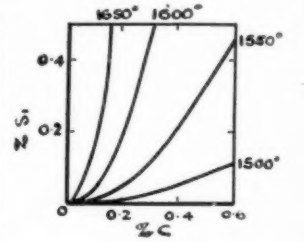


Fig. 6.—Calculated relation between carbon and silicon in equilibrium with silica at one atmosphere pressure and at the indicated temperatures.

The mechanism of the carbon boil in open-hearth and electric furnaces has been the subject of many investigations. Normal equilibrium relationships are often inapplicable because of the difficulty in releasing the carbon monoxide formed. No bubbles can form in the liquid because initially the bubble is infinitely small and the surface tension therefore infinitely large, forcing the gas back into solution. The pressure on a bubble exerted by tension in the surface is :—

$\frac{2\pi r S}{\pi r^2}$ when r is the bubble radius and S is the unit surface tension. Using Bircumshaw's[5] value of S for liquid steel, 1,500 dynes per centimetre, the bubble capable of formation under the pressure of one atmosphere would be 0·06 millimetre across. Bubble formation is, therefore, very difficult at the liquid-liquid interface and only becomes reasonably easy at the liquid-solid interface if the latter has adsorbed gas films or contains gas-filled crevices too small to be filled by the liquid metal owing to its surface tension. Körber and Oelsen,[6, 7] during experiments on the carbon-iron oxide equilibrium in silica crucibles, found that the carbon-iron oxide product could attain ten times its theoretical equilibrium value if the crucible surface was glazed. If a rough body was introduced or if the surface of the crucible was scratched with an iron wire, an extremely vigorous boil would start. Larsen[8] found that under works conditions in open-hearth furnaces a constant " head " of dissolved iron oxide in excess of the equilibrium value was necessary to maintain a steady boil and

4 Schenck. *The Physical Chemistry of Steelmaking*, p. 147.
5 Bircumshaw. *Philosophical Magazine* (1934), Vol. 17, p. 181.
6 Körber and Oelsen. *Naturwiss* (1935), Vol. 23, p. 462.
7 Körber and Oelsen. *Kaiser Wilhelm Inst. fur Eisenforschung* (1935), Vol. 17, p. 39.
8 Larsen. *Metals Technology*. April, 1941.

that this did not vary with the rate of carbon removal. The carbon-iron oxide reaction, however, can approach equilibrium at the gas-liquid interface because the carbon monoxide can escape. The molecular concentration of carbon is higher than the iron oxide concentration and it diffuses faster, so the rate of carbon supply is not the limiting factor. The supply rate of iron oxide is certainly high enough and it is the rate of diffusion of iron oxide in the layer immediately below the air-metal interface that governs the reaction speed. Factors affecting this are primarily air supply, temperature and the depth : diameter ratio of the converter.

Most of the iron oxide dissolved in the bath is formed by direct oxidation, though some enters from the slag. When the rate of oxidation exceeds the rate of diffusion, the excess iron oxide formed is blown across the bath into the slag. Iron oxide then passes from the slag to the metal in an attempt to satisfy the partition coefficient. It cannot do this until nearly all the carbon, manganese and silicon have been eliminated as manganese and silicon immediately react with iron oxide and so does the carbon provided that the reaction product, carbon monoxide, can be released.

The reason why the carbon-iron oxide reaction can proceed as fast as the rate of diffusion of the latter will permit it is because that, as there is a gas-metal interface, the carbon monoxide formed can escape into the air and burn in the normal manner. Despite the high rate of carbon removal, conditions are at all times approaching equilibrium as far as carbon and iron oxide are concerned. Steel from the side-blown acid converter, therefore, probably contains less iron oxide at a given carbon content than that made by any other process.

Silicon Reduction

Silicon pick-up can occur in all acid steelmaking processes and that taking place in the acid side-blown converter is shown and plotted against temperature in Fig. 5.[1] Deviations from the straight line relationship can probably be explained by variations in carbon and therefore iron oxide content. Darken[3] has calculated the relationship between carbon and silicon in equilibrium with silica at one atmosphere pressure using Fig. 1 and Chipman and Samarin's[9] table for the carbon-iron oxide equilibrium. This is reproduced as Fig. 6, indicating at least qualitative harmony with converter reactions because it shows that the amount of silicon reduced back into the metal increases with temperature. The actual silicon increment met with in practice is not usually as high as this as iron oxide is still being supplied to the bath which is not therefore in equilibrium with silica. Once the blow stops, the tendency for the silicon to rise is counteracted by the fall in temperature which lowers the amount of silicon in equilibrium with iron containing a given percentage of carbon. As the area of metal in contact with the comparatively pure silica lining is three to five times the area in contact with the slag, containing only 60% silica, it is logical to assume that it is the silica of the lining, not that of the slag, that is reduced. Silicon pick-up is not in itself indicative of good or bad practice, merely that the metal has reached a certain temperature. Harmful features do arise, however, if the bath temperature is allowed to fall whilst conditions are still oxidising, especially at the end of a heat. Silicon is oxidised forming silica or complex inclusions which have little time to rise up into the slag.

Conclusion

It is not claimed that the theories that have been briefly outlined tell anything like the complete story. Obviously a large amount of experimental work remains to be done and a more thorough application of the principles of physical chemistry. If the reactions taking place in the acid side-blown converter can be further elucidated and controlled, this method of steelmaking, given modern plant and lay-out, still has many advantages in foundries making certain types of steel castings.

9 Chipman and Samarin, *Trans. A.I.M.E.* (1937), Vol. 125, p. 331.

Mond Nickel Fellowships

Mond Nickel Fellowships will be awarded to persons of British Nationality educated to University degree or similar standard though they need not necessarily be qualified in Metallurgy. There are no age limits, though awards will seldom be made to persons over 35 years of age. Each Fellowship will occupy one full working year. It is proposed to award up to five Fellowships each year of an average value of £750.

It should be noted that the main object of these Fellowships is to assist persons capable of appreciating and applying the results of research, rather than to encourage research itself. Consider the following objects :—

(*a*) To allow selected persons to pursue such training as will make them better capable of applying the results of research to the problems and processes of the British metallurgical and metal-using industries.

(*b*) To increase the number of persons who, if they are subsequently employed in executive and administrative positions in the British metallurgical and metal-using industries, will be competent to appreciate the technological significance of research and its results.

(*c*) To assist persons with qualifications in metallurgy to obtain additional training helpful in enabling them ultimately to assume executive and administrative positions in British metallurgical and metal-using industries.

(*d*) To provide training facilities whereby persons qualified in sciences other than metallurgy may be attracted into the metallurgical field and may help to alleviate the shortage of qualified metallurgists available to industry.

They will be awarded to selected candidates who wish to undergo a programme of training in industrial establishments and will normally take the form of travelling Fellowships : awards for training at universities may, however, be made in special circumstances.

Applicants will be required to state the programme of training in furtherance of which they are applying for an award as well as particulars of their education, qualifications and previous career. Full particulars and the necessary forms of application can be obtained from The Secretary, Mond Nickel Fellowships Committee, 4, Grosvenor Gardens, London, S.W. 1. Completed application forms will be required to reach the Secretary of the Committee not later than September 1st, 1947.

Phosphorus and Sulphur Equilibria Between Liquid Iron and Slag

An equilibrium study of the distribution of phosphorus between liquid iron and basic slags has recently been made by T. B. Winkler and J. Chipman, who considered that the published information on dephosphorisation was either too general and qualitative to be of any practical use, or the information that was quantitative had too many limitations to be of any use to steelmakers.

Experiments were, therefore carried out in an induction furnace with a carbon arc slag heater to investigate the factors controlling the distribution of phosphorus between a molten iron bath and a basic slag at equilibrium. In order to determine the rate of establishment of equilibrium conditions within the furnace, radioactive phosphorus was introduced as a tracer, and, after the addition, metal samples were taken every five minutes for forty minutes and the amount of radioactive phosphorus determined in each sample. By such a test equilibrium was found to be re-established in fifteen minutes after it had been disturbed by a furnace addition or by a temperature change. In the course of the investigation 11 experimental heats were made and a total of 98 pairs of slag and metal samples were taken, each pair being accompanied by a temperature measurement.

From the results obtained, a liquid-slag constitution was developed, which included the following compounds :—

1.	Dicalcium Silicate ..	$4\,CaO.\ 2\,SiO_2$
2.	Monocalcium Silicate..	$2\,CaO.\ 2\,SiO_2$
3.	Free Lime	CaO
4.	Tetracalcium Phosphate	$4\,CaO.\ P_2O_5$
5.	Ferrous Oxide.. ..	FeO.
6.	Monocalcium Ferrite ..	$CaO.\ Fe_2O_3$
7.	Monocalcium Aluminate	$CaO.\ Al_2O_3$
8.	A Complex Phosphate	$4\,CaO.\ P_2O_5.\ CaF_2$

The magnesia (MgO) and manganese oxide (MnO) were treated as though they had the same basic behaviour as lime (CaO).

A value for the dissociation constant of the calcium orthosilicate at steelmaking temperature was determined according to the following expression.

$$(4\,CaO.\ 2\,SiO_2) \rightleftharpoons (2\,CaO.\ 2\,SiO_2) + 2\,(CaO')$$

$$K_D = \frac{(2\,CaO.\ 2\,SiO_2)\,(CaO')^2}{(4\,CaO.\ 2\,SiO_2)}$$

$$K_D = 0{\cdot}01 \text{ (independent of temperature)}$$

An equilibrium constant for the dephosphorisation of molten iron by a basic slag was calculated. The expressions for the chemical reaction of dephosphorisation and the dependence of the equilibrium constant on temperature was as follows :—

$$2P + 5O + 4\,(CaO') \rightleftharpoons (4\,CaO.\ P_2O_5)$$

$$Kp = \frac{(4\,CaO.\ P_2O_5)}{[\%P]^2\,[\%O]^5\,(CaO')^4}$$

$$\log Kp = 71667/T - 28{\cdot}73.$$

The effect of slag composition on the activity of slag iron oxides and on the free lime content was obtained by ternary diagrams which take into account all of the slag oxides. Dephosphorisation was also found to be improved by decreased temperature, increased from iron oxide content of slag and metal, increased base-acid ratio of slag resulting from either increased lime content of the slag, increased magnesia content of the slag, increased manganese oxide content of the slag or decreased silica content of the slag. Fluorspar additions to the slag had no adverse effect on the dephosphorising power of the slag.

Sulphur equilibria between liquid iron and an assortment of basic slags ranging from strongly basic to slightly acidic were studied by N. J. Grant and J. Chipman from a long series of experimental heats made in an induction furnace. An extremely wide range of slag compositions in both the simple and complex slag systems was investigated with temperature as an additional variable. The constitution of the liquid slag was formulated on the basis of attraction between basic and acidic quantities, the basic oxides CaO, MgO and MnO being taken in all ranges to be equal on a molecule per molecule basis, and the following molecular ratios were taken as necessary for a neutral slag.

2 Base : 1 SiO_2
4 Base : 1 P_2O_5
2 Base : 1 Al_2O_3
1 Base : 1 Fe_2O_3

When insufficient base was available, Fe_2O_3 was considered neutral and added to the FeO. FeO was considered uncombined in all cases. The remaining base or acids after these combinations were fulfilled were then added and designated as the "excess base or acid count" expressed in molecules per 100 grams of slag.

From curves of the sulphur ratio S/S' where S is the slag sulphur and S' the metal sulphur in per cent. values, against the excess base or acid count it was concluded that in slags of the type investigated, MnO and MgO on a molecule per molecule basis were as good desulphurisers as CaO, fluorspar was neutral and did not affect the sulphur ratio, alumina required the same number of molecules of base to neutralise as did silica and slag FeO (from 3 to 70%) had only a dilution effect on the sulphur ratio. Temperatures in the range 1540° to 1660° C. showed no measurable effect on the sulphur ratio. Temperatures greater than 1670° C. appeared to have a small harmful effect, while temperatures below 1540° C. and/or FeO below 3% appeared to have a beneficial effect on desulphurisation. Sulphur distribution was controlled almost entirely by the excess acid or basic count and the relationship was almost linear.

Basic open-hearth values of the sulphur ratio showed reasonably good agreement with the equilibrium values determined for the same basicity, regardless of carbon content. Sulphur equilibrium was closely approached during refining in the open-hearth and the sulphur ratio in low-carbon heats reached its maximum value at about 8.

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The Iron and Steel Institute

Summer Meeting Held in Switzerland

An excellent programme had been drawn up for the above meeting, which not only included technical sessions at which several important papers were discussed, but included a banquet, visits to many works and laboratories, as well as visits to different parts of Switzerland. There can be no doubt that members and their friends who attended this meeting will regard it as a means of developing and strengthening the friendly relations which already exist between the peoples of Britain and Switzerland. It would be impossible to reproduce the atmosphere here, but an outline of the proceedings and of the technical sessions will be of interest.

THE opening session of the summer meeting of the Iron and Steel Institute in Switzerland was held in the great hall of the Swiss Polytechnic in Zürich on July 10th, 1947, with Dr. C. H. Desch, F.R.S., President of the Institute, in the Chair.

Address of Welcome

Dr. A. ROHN, President of the Swiss Technical School Council, speaking in French, offered a cordial welcome to the Institute, and said that in meeting in the Polytechnic the Institute was meeting, as it were, on the soil of the Swiss Confederation itself, since the Polytechnic was the only educational establishment for which the Swiss Government was responsible, and was evidence of the interest taken by the Confederation in applied science.

Switzerland lacked natural resources and suffered from many other disadvantages, so that the development of her industries might seem to be something of an enigma. The fact was, however, that these unfavourable economic conditions had obliged the country to make the best possible use of its intellectual resources and manual skill. " The beauty of our country and the eternal snow of our mountains (the source of our water-power) are almost our only natural resources," he said, " and our people, if they are to maintain a high standard of living, must do so by hard work. We are obliged to export a large part of our production, and we consume in Switzerland only 60% of our total production and only 15% of our production of machinery."

Switzerland had to buy her raw materials abroad, and, the level of wages being high, Swiss exports were possible only because of the high quality of her products. It was the absence of raw materials which had made it necessary to produce goods of the highest quality. All her educational establishments had had to adapt themselves to this necessity, and to train both manual and intellectual workers to produce work of very high quality.

In the domain of applied science this was the task of Polytechnic, which was called on to train young engineers who had already received a sound fundamental scientific training to apply in it a way showing initiative, and sometimes in a creative spirit. During the past year the Swiss Government had granted the sum of 27 million francs to enlarge the laboratories and research institutions of the school, because scientific research was a necessary complement to higher technical education.

The visits to different parts of the country to be made by the Institute would give those taking part in them some idea of the varied nature of Switzerland. They would meet everywhere a reception of democratic simplicity. Life in a country much of which was unproductive, and the constant view of their high mountain peaks, had imposed on the Swiss people this simplicity, and had stabilised their political conceptions. The members of the Institute, however, could be certain that all the industrial enterprises and other places which they would visit would be very happy indeed to receive them, because Switzerland had always attached the greatest importance to her relations with Great Britain. Cultural, industrial and economic relations began with relations of friendship between peoples.

" We are certain," Dr. Rohn said in conclusion, " that your visit to Switzerland will contribute to the development and strengthening of the friendly relations which already exist between us, and create new bonds between you and your Swiss colleagues. I sincerely hope that these relations of friendship and sympathy will develop. On behalf of all your Swiss friends I wish to express our good will towards your eminent President and for the growth of your Institute and the influence which it exerts in an essential domain of human activity, that of iron and steel, which rules the world in time of peace and in time of war.

Dr. C. H. DESCH thanked Dr. Rohn for his address and for his share in the magnificent reception which the Institute received in Zürich. He agreed most heartily with what Dr. Rohn had said as to the relations between their two countries. Those relations had been of the friendliest and closest kind for very many years ; they held a common democratic tradition in which they had to some extent led the world. Many would recall Wordsworth's famous lines—

" Two voices are there,
One of the sea, one of the mountains ;
Each a mighty voice.
In each from age to age thou didst rejoice,
They were thy chosen music, Liberty."

Wordsworth went on to refer to the democratic traditions of the two countries of which he was speaking, Switzerland and England. That poem of Wordsworth's expressed what had been the feelings of England for Switzerland over a long period of years ; and it was a particular pleasure that, now that the war was over, it was possible once again to pay a visit to Switzerland, with its magnificent tradition of liberty and at the same time with its very high technical standards.

TECHNICAL SESSIONS

Immediately following the opening proceedings the remainder of the meeting that day was devoted to the

presentation and discussion of the following papers :—

"Electric Smelting" and "The Production of Iron and Steel with Oxygen-enriched Blast," by Professor Dr. R. Durrer; "Possibilities for the Extended Use of Oxygen in the British Steel Industry," by M. W. Thring; "Hydrogen and Transformation Characteristics in Steel," by Professor J. H. Andrew, H. Lee, H. K. Lloyd and N. Stephenson (presented, in the absence of the authors, by H. H. Burton); and "Hydrogen in Steel Manufacture," by Dr. C. Sykes, F.R.S., H. H. Burton and C. C. Gegg.

At the second session, held the following day, the following papers were presented for discussion :—

"Observations on Conducting and Evaluating Creep Tests," by W. Siegfried; "Steel for Use at Elevated Temperatures," by Dr. C. Sykes, F.R.S. (Second Hatfield Memorial Lecture); "Requirements of Steel for the Production of Gas Turbines and Experience with Gas Turbines in Metallurgical and Associated Plants," by H. R. Zshokke and K. H. Niehus; and "The Scaling Behaviour of High-strength Heat-resisting Steels in Air and Combustion Gases," by W. Stauffer and H. Kleiber.

At the conclusion of the session Mr. D. A. Oliver then gave a short resume of Special Report No. 38 ("A Symposium on Powder Metallurgy," which is reviewed elsewhere in this issue) and of the discussion held in London on June 18th and 19th, 1947.

The papers and discussions are summarised in the following notes.

THE PRODUCTION OF IRON AND STEEL WITH OXYGEN-ENRICHED BLAST

By R. Durrer

ATMOSPHERIC oxygen, used for the production of iron and steel, is available without cost, but it is united with about four times its volume of nitrogen, which must be compressed, circulated, heated and purified together with it. Since the production of oxygen-enriched air has become cheaper the economical aspects of using it in the iron and steel industry are discussed. Dr. Durrer points out that at present the energy consumption of oxygen-enriched air is about 0·5 kwh/cu. m. of pure oxygen which, at the rate of 2 centimes/kwh corresponds to 0·15d/cu. m. The cost of compressing atmospheric oxygen and delivering it to the blast furnace is about 0·5 centimes/cu. m. or about 0·07d, which must be taken into account. These additional costs can be assumed to be higher in ordinary blast-furnace practice than with the use of oxygen-enriched blast. Under this assumption the actual cost of 1 cu. m. of oxygen in oxygen-enriched blast amounts to 2 centimes or 0·3d cu. m.

For each ton of coal used about 4 tons of blast are blown into the furnace and about 5 tons of gas leave it at the top. This gas carries more than half the heat required for the production of iron, from the hearth into the upper zones. This heat must be used in the furnace as far as possible, and this is done by its transmission to the burden, hence the reason for blast furnaces being built in heights up to about 100 ft.

As the oxygen content of the blast is increased the amount of sensible heat contained in the gas becomes correspondingly smaller, and the temperature gradient of the rising gas greater. In ordinary blast-furnace practice the top-gas temperature amounts to several-hundred degrees centigrade. As the oxygen content is increased the top-gas temperature decreases gradually, reaching practically its lower limit at about 100° C. Until this limit is reached the drop in the temperature of limit is reached the drop in the temperature of the top gas causes a saving in fuel, the extent of which corresponds to the amount of utilised sensible heat of the top gas. Further oxygen enrichment of the blast does not cause an increased saving; for the furnace top becomes wet, and the upper part of the stack cold and unfit to work. It would be a mistake, however, to conclude from this fact that a still higher oxygen content would be useless or even undesirable.

In fact, no further heat of the top gas can be absorbed, since there is practically none left, but this is not the sole purpose of smelting with oxygen-enriched blast. Of much greater importance is the possibility of constructing lower furnaces as the 100° C. zone drops in the furnace. In this way a furnace of only a few metres height is required with practically pure oxygen, which allows the use of low-class fuel, so that a new basis for the smelting process is obtained, not only from the metallurgical but also from the economic point of view.

On oxidising with oxygen-enriched blast in the converter, so much heat is saved compared with the use of atmospheric oxygen that about ½ ton of scrap can be melted down per ton of iron blown. If this were the only way of transforming pig iron into steel, the heat saved would be sufficient for more than half of the scrap nowadays remelted at a high expenditure in energy, mainly in the open-hearth furnace. Thus one of the main duties of the latter furnace could be taken on by the Bessemer converter with the aid of oxygen-enriched blast. The objection raised against Bessemer steel on account of its higher nitrogen content would no longer be justified; on the contrary, on blowing with oxygen-enriched blast the nitrogen content of Bessemer steel would be lower than that of open-hearth steel.

ELECTRIC SMELTING

By R. Durrer

THE development of electric smelting furnaces is outlined, with special reference to the low shaft furnace. The reactions taking place in electric smelting are discussed and compared with those of the blast furnace, particular consideration being given to the energy consumption in the two types of furnaces. In considering the possibilities of the future development of electric smelting Dr. Durrer points out that electric smelting is one of the rare examples in which the efficiency of both types of energy is about the same; strictly speaking, coal is even slightly superior. It would thus be a mistake to use hydro-electric power for smelting in the place of coal, while there is still the possibility of replacing coal in cases in which it is not utilised so efficiently as electrical energy.

Even though electric smelting is on the whole restricted to comparatively narrow limits, in certain regions there is the possibility of remarkable development. This can be enhanced by adapting the energy consumption to local conditions and by using low-quality and, consequently, inexpensive material. It is likely that electric smelting will extend also to other districts as soon as it becomes possible to lower the energy consumption appreciably and to use any quality of coal. A condition for this is the complete utilisation of the coal—i.e., the complete combustion of carbon to carbon dioxide. A development of this kind was initiated by Wiberg, who adapted

his sponge-iron process to the use of electric furnaces; but even so the energy consumption is said to amount to about 1,500 kWh./ton. Another promising attempt consists in the use of the open low-shaft furnace with the introduction of blast just below the top, which causes the combustion of the rising gases.

POSSIBILITIES FOR THE EXTENDED USE OF OXYGEN IN THE BRITISH IRON AND STEEL INDUSTRY

By M. W. THRING, M.A., F.Inst.P.

RECENT developments in methods of manufacturing oxygen both in the range of purity 80–100% and in the range 40–60% make its use for combustion of fuel in the steel industry a very important practical possibility. Oxygen could be used in the iron and steel industry on a large scale in two ways; one is equivalent to a small percentage reduction of the nitrogen heated in the combustion process by mixing the oxygen-enriched air with the remainder of the combustion air; the other makes separate use of the small quantity of oxygen-enriched air. In the former category, comes the use of oxygen in the blast-furnace and in the Bessemer converter. It has been concluded that if anyone is prepared to face the capital cost of building a plant capable of producing 200 tons of oxygen per day to supply a blast-furnace, then it would be likely to give an overall economy of fuel if applied to a furnace producing ferro-manganese. The use of oxygen in the Bessemer converter, or what is equivalent, its use in the bath of an open-hearth furnace, are very promising lines which can be investigated with a relatively small oxygen plant.

The use of oxygen in the open-hearth furnace comes into the second category since this development is only of interest if (*a*) the use of oxygen is confined to the "critical period" of the melt and (*b*) the oxygen-enriched air is introduced not with the main air stream but in such a way that it gives greatly improved mixing and combustion conditions. The development of alternative methods of producing oxygen-enriched air such as the Mazza centrifugal separator should also be carried out in parallel with any experiments on the application of oxygen produced by liquefaction of air.

JOINT DISCUSSION

Mr. R. MATHER (Skinningrove Iron Co., Ltd.), in his comments said that the statements made by the authors, and their explanations of why they expected to derive advantage from the use of oxygen with the existing type of blast furnace, were hopeful. He thought that in the next ten to twenty years positive developments would take place in that direction, and there was no reason why those developments should not be combined with those in the other direction in which blast furnace development was taking place to-day, the use of high top pressures, about which information based on actual operating practice was beginning to be received.

When in America just over twelve months ago he saw a very large oxygen plant being built at one of the large American steelworks. It was nearing the stage when it would be ready for operation, but whether it had since been put into operation he did not know. It was a fact, however, that in America very large oxygen plants were being built.

Mr. Thring pointed out that the use of oxygen in the steel-making process would have considerable advantages in three or four directions so far as the Bessemer process was concerned. An additional point was the possibility of using the Bessemer process for pig irons of intermediate composition between the only two ranges of composition for which that process could now be used—namely, the low phosphorus, hematite-making, acid Bessemer, which had almost disappeared except for a little in the U.S.A., and the very high phosphorus pig iron, of 1·7%, 1·8% and over. It was not possible to-day to use the basic Bessemer process for irons of intermediate phosphorus composition. One reason for that limitation was that with phosphorus contents of 0·7% to 1% there was not enough heat available, but with oxygen in the blast it would be possible to get a hotter metal, so that it might be feasible to consider the use of the basic Bessemer process.

Mr. E. C. EVANS (London) said a debt of gratitude was due to the authors for their contribution to what was probably the most important subject in metallurgy to-day. If it was possible to reduce the power cost and capital charges of oxygen production, the possibilities of using oxygen became much more attractive. That could be done by building big oxygen plants; the cost went down almost in a hyperbolic curve as the quantity of oxygen increased.

Mr. Thring had referred to an expenditure of half a million pounds to test whether oxygen was any use in the blast furnace. There was another possibility, which was being developed in the U.S.A. where most of the big plants were now testing out the use of oxygen in their open-hearth furnaces.

There were two main lines of atack. One was the use of oxygen for combustion, and in that direction a few companies had obtained some very interesting results. With oil as the fuel, almost any modification of the oil burner to allow the introduction of oxygen produced useful results, and, adding the oxygenated air or oxygen blast during the melting-down period, they had been able to increase production by something of the order of 30% with no greater wear and tear on the refractories. When oxygen was used with a gas, however, burner design became much more important, and he liked the idea put forward by Mr. Thring for the direct introductian of oxygen into the gas flame along the lines mentioned.

The other line of development was the use of oxygen in the bath. For low carbon steels that had given most valuable results, the increase in output being of the order of 30–33%. One works, which had introduced oxygen into the combustion air and into the bath, had reduced the time of melting from tap to tap from 11½ hours to a little over 6 hours, which meant a tremendous increase in output.

Dr. MAGNUS TIGERSCHIOLD (Jernkontoret, Stockholm), said that he, like Mr. Evans, saw what was being done in America, and he came to the conclusion that it was now possible to make cheap oxygen in large quantities. It must also be remembered that during the war Leipsic and Magdeburg were supplied with town's gas made by the partial combustion of lignite with pure oxygen. Already plants of large size were working.

One fact which had not been mentioned was that at Trail in Canada, large-scale experiments had been carried out using oxygen and steam in a gas producer; from an ordinary gas producer with revolving grates they produced quite easily an ordinary coal gas of 2,500 calories/cubic metre. That way of using oxygen had the great advantage that the oxygen was used in the steam which enriched the gas.

Dr. L. JENICEK (Czechoslovak National Steel Corporation) referred to earlier work in which Dr. Durrer spoke of

coke or coal of inferior quality, but now he spoke of coal. It would be of great interest to have more exact indications of the calorific value of the fuel under consideration in the present paper. Dr. Durrer, however, again gave ground for hope, and assumed that it was possible to consume only 500 kg. of coal per ton of iron and only 200 cubic metres of oxygen. Were those figures based on practical experience?

He did not believe that the use of oxygen in the blast furnace would be of general interest, and the low-shaft furnace seemed to him not very possible in practice. But there were other possibilities, and in particular its use in the Bessemer process and in the open-hearth furnace was of great interest. Moreover, the production of rich gas from an inferior coal was important.

Mr. A. G. Robiette (John Miles & Partners (London), Ltd.), endorsed most heartily Dr. Durrer's remark that if an oxygen-rich mixture was used for blowing the blast-furnace it was conceivable that one would end up with a furnace which did not look like a blast furnace at all. Personally, he thought that that fact was fundamental and that it must be realised that the use of oxygen brought in an entirely new set of physical conditions and would upset all previous ideas of what iron and steel plant looked like.

The main application to steelmaking should be the blowing of pig iron with oxygen for conversion into steel. He and his colleagues had been working on this process for some years; they had blown heats with 90% oxygen on a scale of 2 tons at a time and in a period of approximately 30 minutes, and had produced steel some of which had gone into commercial products. Arrangements were now being made to carry out the process on a large scale with vessels of 10 tons capacity. This would prove, he believed, to be one of the major developments in the iron and steel industry.

Mr. F. G. Kerry (Canadian Liquid Air Company, Montreal) said that a little over a year ago, when the Steel Company of Canada tried out its first test in an open-hearth furnace, their idea was to reduce production costs by increasing the production of steel per hour and per furnace. Obviously the way to do that was to increase the charge and increase the fuel rate per hour.

To burn fuel in a very quick manner it was necessary to use something more than just air. Using almost pure oxygen through the burner to give the primary combustion it was possible to increase the fuel rate (he was speaking now of oil) by as much as 45%. This would give increased production, and, speaking rather conservatively, they felt that they could increase the production of their open-hearth furnaces by at least 30%. Moreover, although the fuel rate was increased by as much as 45% during the melting down period, there could actually be a gain in fuel. It was possible to knock it down by as much as 25%. That, however, was not always the case; it applied to open-hearth furnaces in which 40–50% of the charge was hot metal or hot pig iron. In furnaces using entirely scrap, the effect on the fuel consumption was not as interesting.

With regard to the amount of oxygen used, a very good figure to take was about 850 cu. ft./ton of steel produced, when dealing with half cold and half hot metal, and about 1,000 cu. ft./ton for all cold-charge furnaces.

Mr. A. Robinson (Appleby-Frodingham Steel Co.) thought that the best opportunities for using oxygen in open-hearth furnaces were during the melting stage of the process. He was not so impressed by the idea of the blowing of oxygen into the bath itself. If the furnace was hot enough and the charge was working well, the refining would be done almost as quickly as it was possible to control it, and in the making of high-class steels it was necessary to have a little time and very good control over the steel bath in order to get the quality demanded.

The use of oxygen in the blast furnace offered very interesting possibilities in England, because in England they had mostly very soft ores, and in many districts very soft cokes. If it was possible to have a low blast furnace and avoid the cost of the extremely expensive pre-preparation plants which were being installed, the saving might pay for the oxygen plant.

Mr. J. W. Reber (Wellman Smith Owen Engineering Corporation, Ltd.), said a higher yield with an open-hearth furnace using oxygen-enriched air and oil was not so much a question of the increase in flame temperature as such, though that did occur, but rather a question of quicker mixing. In an ordinary open-hearth furnace one got only about 80% of the actual temperature in the furnace; the other 20% was lost in internal combustion. Using oxygen, and especially, as Mr. Thring had shown, very close to the gas stream, one got much quicker diffusion and therefore a higher temperature. It was that which gave the high throughput in the open-hearth furnace.

Professor Dr. R. Durrer, in reply, thanked those who had taken part in the discussion for the ideas which they had put forward. He agreed with Mr. Thring and other speakers that the tests which were being carried out in the open-hearth furnace and in the blast furnace were of the greatest interest, because production costs might be reduced and the capacity of the iron and steel industry of a country might be increased. If by using oxygen in the blast furnace and the open-hearth furnace it was possible to increase production by 10–20%, it meant that the capacity of the iron and steel industry of a country might be increased by that amount.

The ideas which he himself had put forward related to the more distant future. He knew, of course, that there were very many difficulties to be overcome, but if one was convinced of the correctness of an idea one would not be afraid of difficulties but would overcome them. It might not be possible to make use of these new ideas in the immediate future, but it was necessary to consider the more distant future as well, when the time came for the present blast furnaces and open-hearth furnaces to be replaced by others.

The President said that some years ago he had been asked by the Federation to prepare a report on processes devised for producing steel without using the blast furnace He made a review of 140, of which 1 was working. Accounts of them were found in various published papers, and company prospectuses. Since then a great deal of valuable work had been done on the fundamentals of smelting, and the possibility of using oxygen had become a real one, so that the subject had been presented that day from a new point of view. The very bold and striking suggestions which had been made that day would be discussed with the greatest possible interest.

HYDROGEN AND TRANSFORMATION CHARACTERISTICS IN STEEL

By Professor J. H. Andrew, B.Sc., H. Lee, B.Eng., Ph.D., H. K. Lloyd, B.Sc. and N. Stephenson, B.Met.

THE main object of the extensive work described in this paper has been to establish the relation between hydrogen evolution and the transformation characteristics of steel. It has involved a comprehensive study of the evolution of hydrogen from steel, and results

obtained for 22 different steels, hydrogen-soaked and cooled in vacuum under identical conditions, are reported. It is shown that in all cases relations between hydrogen evolution and transformation characteristics are marked and that there is a pronounced increase in the rate of evolution corresponding to the gamma-alpha change. The manner in which hydrogen is evolved from a steel is shown to be closely linked with the mode of transformation, but such a correlation does not necessarily determine the amount of hydrogen retained after cooling.

The effect of alloying elements upon hydrogen evolution from steel is discussed, and it is deduced that hydrogen diffusivity in the alpha range may vary with the composition and treatment. It was found that when nascent hydrogen was generated by electrolytic action on the surface of a steel specimen, both the rate of diffusion and the solubility at room temperature depended upon the structure of the steel.

Experiments on the removal of hydrogen from steel under isothermal conditions, as outlined in a previous paper, have been continued, and the results confirm the conclusion that the optimum temperature of hydrogen removal corresponded with a rapid transformation. Crack formation in isothermally treated specimens has been discussed, and certain anomalous results of crack formation previously observed for plain carbon and nickel steels are explained in terms of the effect of structure upon hydrogen diffusivity and solubility at room temperature.

In the presence of hydrogen, the transformation of a 3% chromium steel under isothermal conditions was slightly slower at 700° C., otherwise hydrogen was found to have no retarding effect upon isothermal transformation. The nature of the isothermal-transformation product has been studied, and it is shown that with a 3% chromium steel containing 0·2% of carbon, 480° C. was found to be the critical temperature dividing the formation of chromium carbide (Cr_7C_3) and cementite (Fe_3C). Isothermal-transformation diagrams based upon dilatometric measurements are given for the chromium steel as well as for a $3\frac{1}{4}$% nickel steel.

Hydrogen embrittlement was found to vary with the thermal treatment of steel, and it is shown that with a 3% chromium steel the presence of hydrogen to the extent of 3 c.c./100 g. may or may not cause an embrittling effect, according to treatments given, and the elongation and reduction of area are affected differently by hydrogen. It was also found that the distribution of hydrogen in a tensile test-piece had a marked effect upon its mechanical properties.

The authors consider that hydrogen embrittlement and hair-line cracks are closely associated with each other, and that hydrogen diffusivity and solubility are the controlling factors for both. The view previously expressed to explain hair-line-crack formation has been modified, in that the sudden evolution of hydrogen at the crack formation does not necessarily involve the breakdown of a hydrogen-rich constituent. Whilst hydrogen is the fundamental cause of hair-line cracks, stresses are important in that they may affect the diffusivity and solubility of hydrogen. Unless results of hydrogen diffusivity and solubility in steel for various conditions are available and the effect of structure and stresses upon them is thoroughly understood, controversies regarding the cause and mechanism of hair-line-crack formation cannot be settled.

HYDROGEN IN STEEL MANUFACTURE

By C. Sykes, D.Sc., F.R.S., H. H. Burton and C. C. Gegg, B.Sc.

In this paper the authors have recorded a number of observations on the hydrogen content in steels at different stages of manufacture, for example, liquid steel, ingots, billets, forgings, etc., and to consider these results in terms of the various theories put forward in the literature.

Experiments on semi-finished products confirmed the results of previous work on steels artificially impregnated with hydrogen and indicated that ductility is reduced with hydrogen contents in excess of 2 c.c./100 g. Even when steel is melted under carefully controlled conditions, hydrogen contents of 4–6 c.c./100 g. are to be expected, which will adversely affect ductility if not removed. A study of the effects of various heat-treatments on hydrogen contents and susceptibility has shown that relatively high hydrogen contents do not automatically lead to hair-line cracks. No conclusive evidence was obtained on the question of segregation, although some alloy-steel ingots and forgings showed wide variations in hydrogen content. On the basis of certain assumptions, data on permeability and solubility have been used to calculate values for the diffusivity of hydrogen, which have made possible the prediction of the rate of loss of hydrogen from steels at temperatures down to 400° C., at relatively high hydrogen concentrations. The results of the experiments are discussed in relation to the theories put forward by other workers on the subjects of hydrogen in steel and hair-line-crack formation.

JOINT DISCUSSION

The President (Dr. C. H. Desch, F.R.S.) said that the above two papers represented a very large amount of work undertaken by the Hair-Line Crack Sub-Committee. When the problem became important, the question of hydrogen was at once raised. There were some sceptics who were doubtful whether hydrogen played any part in the phenomenon at all, but he thought that the work which had gone on had shown that, whilst other factors had to be taken into account, hydrogen was the most important of all.

He paid tribute to the way in which the various British steel firms had co-operated in the research which had been carried out. It had involved a great deal of work in the laboratories and in the works themselves, and often meant making ingots and forgings which it was known would have to be scrapped afterwards. Although the problem had not been completely cleared up, very great progress had been made. At first sight it might seem that the solubility of so small an atom as hydrogen and its diffusion through a lattice would be very simple, but it had proved to be exceedingly complex, and in the second paper there was considerable discussion of the physics of the process. So far as a practical solution was concerned, he thought that many steelmakers knew how to produce steel free from hair-line cracks provided they had plenty of time. It was always when pressure of work had been very acute and forgings had to be prepared quickly that there had been most trouble with hair-line cracks.

Dr. F. D. Richardson (British Iron and Steel Research Association), dealing with the problem of diffusion, referred to in the second paper, said he had been struck by the very low temperature coefficient used. The authors gave the surprisingly low figure of 2. Other metals did not show

anything below 6, and other workers on iron at low temperatures had produced figures of the order of 9 and 10. It seemed to him that the assumption on which the coefficient had been obtained was, at the low temperatures, an invalid one, and that the concentration gradient which actually occurred in the sample was not a gradient from the solubility at the temperature that was being investigated and not a concentration at all on the vacuum side, but something very much less.

Dr. M. L. Becker (British Iron and Steel Research Association) said it had now been shown that the hydrogen was deleterious, though not the sole cause of cracking. He wondered why more attention was not paid to getting rid of the hydrogen entirely, as Dr. Sykes had suggested. It was in the liquid state that the hydrogen could be got rid of most easily, and he suggested that in the liquid state the hydrogen could be driven out by bubbling through an inner gas. Such an inert gas must clearly not be nitrogen, because that would be absorbed in the steel, while oxygen or CO_2 would react with the steel too rapidly. He could only think, therefore, of carbon monoxide. He felt that if the experiment of bubbling carbon monoxide through had not been tried it ought to be. It might seem a little difficult from a practical point of view, but he felt sure that that could be overcome. By bubbling it through it should be possible to get rid of the hydrogen.

Dr. C. Sykes, in reply, agreed with Dr. Richardson that at temperatures of the order of 350° C. and below the concentration gradient was not equal to the solubility. He was fairly happy, he said, about the position from 350°–650° C. because he had measured the diffusion constant and it fitted, but below 350° C. it went wrong, and either the explanation which Dr. Richardson put forward or the difficulty regarding the surface probably explained the reason; in other words, instead of having the complete concentration gradient one had only a fraction.

With regard to Dr. Becker's point, most steelmakers would like to get rid of the hydrogen, but the difficulty was to do it. On the question of an inert gas, they had bubbled large quantities of nitrogen through liquid steel and it had no effect.

OBSERVATIONS ON CONDUCTING AND EVALUATING CREEP TESTS

By W. Siegfried

IN the temperature range from 600°–650° C. the efficiencies of gas turbines will to some extent bear comparison with those of steam turbines. Raising the temperature of the working medium further increases the efficiency of the gas turbine and enable it to outdistance the steam turbine. The gas turbine, therefore, is bound to give an impetus to the development of heat-resisting steels. The main difficulty encountered is the fact that at these high temperatures the materials used are no longer stable. At a given stress a continuous slow creep begins and leads, after a certain time, to rupture of the metal.

The author examined in some detail the question of how the metals required for highly stressed parts of the gas turbine are to be tested. It is only at very great expense that sustained-load tests with three-dimensional stresses can be carried out at high temperatures. The sole possibility of conducting tests with different stresses at high temperatures is to be found in sustained-load tests with smooth and notched specimens, in which case both the depth and the angle of the notches in the latter bars have to be varied.

The results of these investigations must in some way be transferred to the conditions of engineering practice. As at present not even the rudiments of a system of calculation are available, it is in some circumstances necessary to carry out model tests with individual elements of design, the aim being to reduce the strength of these parts to the terms of the strength of these parts to the terms of the strength of smooth and notched bars.

The author describes sustained-load tests carried out on various highly heat-resistant alloys used in the construction of gas turbines. The results of these tests are evaluated in the light of the main problems presented by gas-turbine design. The tests described also introduce the problems of three-dimensional stressing at high temperatures and the influence of notches on hot strength.

The results of sustained-load tests on smooth and notched bars at high temperatures are set forth and discussed. A decisive influence on deformation figures in the sustained-load test and on the notch toughness is exercised by the testing time. Curves for various steels are given which furnish a good criterion of their toughness.

DISCUSSION

The President (Dr. C. H. Deach, F.R.S.) characterised Mr. W. Siegfried's paper as an important one, which had attracted very much attention in England. For a number of years, he said, extensive researches on the creep testing of materials required to stand high temperatures had been proceeding.

Mr. D. A. Oliver (William Jessop & Sons, Ltd.) said that the British approach to the whole subject was fundamentally different from the approach of the author. They did not know much about it a few years ago, but they did know that it was complicated, and they found so much contradictory information associated with the simplest possible parallel tensile creep specimen or parallel hot tensile test that they had not got to the stage when they would be so bold about advocating the widespread adoption of the notched test-piece. On the other hand, they had not been entirely unmindful of the problems of notches and blade root fixings.

In Great Britain, when they had been concerned with the effect of notches in blade roots they had had recourse to photo-elastic studies, which gave a detailed solution only for the elastic case. They had still regarded that only as guidance and not as a final answer, and when it came to the question of studying the actual blade root fixing they felt that it was misleading to deal only with one blade dummy and one root fixing. They found that it was necessary to consider at least two blade root fixings on either side of a single blade under test. It would be very interesting to know whether the author himself had found that necessary, because there could be violent sideways reaction the moment the blade tried to pull out.

Mr. W. E. Bardgett (The United Steel Companies, Ltd.) said that at normal temperatures it was known that moving parts usually failed at a position of stress concentration, and efforts were directed to minimising the stress by design or by increasing the strength of the material in such a way as to overcome the effects of the stress concentration, such as by nitriding, shot-peening and so on. For high-temperature service, stress concentrations were, of course, a major factor under static as well as dynamic conditions. It was clear, therefore, that the field in which the author had been working was one which warranted the closest study, and the work which he had described could not be too highly praised. It was of interest here to refer to investigations

by a sub-committee of the British Electrical and Allied Industries Research Association on the failure of 0·5% molybdenum steel. This occurred in the form of steam pipes, and led to a recommendation which was of particular interest in its bearing on this subject. The recommendation was that it was highly important that pipes should have smooth and undamaged surfaces, and that grooves, fissures, indentations, hammer-marks and other irregularities which would cause stress concentrations should be prevented or removed. The expressed hope of the committee was that their inquiry would lead to the formulation of some suitable form of test which would ensure material which was not notch sensitive being applied in service. The work of that committee was continuing, and no doubt due regard would be paid to the work of the present author.

The evaluation of notch sensitivity on the basis of the true stress contraction curves and notched specimens was undoubtedly a matter for serious consideration in evaluating materials for high temperature service, but it would be interesting to know how far the author considered that the evaluation on this basis might be simplified. Did he consider it possible to determine the relative notch sensitivity using one selected notch, or was it necessary to make the evaluation on a number of notches, and precisely how was the evaluation of the notch sensitivity made in relation to the S-curve?

Dr. L. Jenicek (Czechoslovak National Steel Corporation) congratulated the author and emphasised the importance of the paper, which showed the importance of the design and form of the bars used at high temperatures, a question which was sometimes neglected. It was due to the influence of Professor Ros and his school that in Switzerland these questions were studied and investigated in all branches of engineering, and that facilitated the work of metallurgists who were concerned with this problem. On the other hand, it proved the necessity of restricting the design and form of the simple test-bar on which the elongation was determined.

The classical creep test which gave good information about the conditions, for example, in the boiler was not sufficient for the solution of the problem of the gas turbine; there it was necessary to use the combined fatigue test and corrosion test, as was proved in papers to be discussed later. He thought that it was very appropriate that the Swiss should initiate international collaboration this field, and the present paper proved their competence to do so.

Dr. C. Sykes, F.R.S. (Firth-Brown Research Laboratories) said he had read the paper with great interest, because the author had had the courage to deal publicly with a subject which had worried a good many metallurgists for a long time. It was an extremely complicated subject, and he felt that at the present stage all that they could say about it was that it was complicated.

With regard to the notch effect, he thought that the theoretical position at high temperatures was very unsatisfactory. He had never been able to understand the arguments of Kuntze, and in any event he thought it was true to say that they were based on pure elastic theory; for example, they assumed a value for the Poisson's ratio which was not the value observed.

Dr. Sykes referred to one of their experimental steels which had been examined. This material had quite a small elongation in the cold, and the reduction of area was about the same as the elongation; in other words, at room temperature there was no necking. At elevated temperatures, however, substantial necking occurred. He thought it was true to say that in that particular steel there were no major cracks; any cracks which started seemed to seal themselves up after a very short distance in. It might be imagined, therefore, that that material was not notch sensitive; yet the fatigue properties of that material when notched were in no way superior to the fatigue properties of other materials which showed marked intercrystalline cracking on ordinary creep testing.

The Author intimated that he would reply in writing, and was thanked by the President for an extremely interesting paper, which would be studied with great care by all those in England who were working on the important subject of creep.

REQUIREMENTS OF STEEL FOR GAS TURBINES

By H. R. Zschokke and K. H. Niehus

THE investigation of the alloys and the methods of testing and examination were thus adapted, during the war, to the determination and control of the various properties, such as the creep rate, time to fracture, and corrosion resistance, within a period of 300 hr., and in some cases 500–1,000 hr. This is clearly illustrated by the numerous papers on gas turbine steels published by the countries which were at war.

When testing and evaluating heat-resistant steels for gas turbines used in peace time on land and sea, as the authors point out, other criteria must be taken into account than in the case of aeroplane turbines, especially those for military aircraft. This is due to the fact that in peace time a life of many years is required, whereas for aircraft turbines a life of a few hundred hours is enough. This difference is especially important in the evaluation of creep tests on steels used for turbine blades. The alterations of the structure after long exposure to high temperatures need further exploration, and the value of various methods applied to raise the creep limit must be studied more carefully. Apart from the creep limit, the fatigue strength is of vital importance to the engineer, and the same applies with regard to the corrosion resistance of the blades and the combustion chamber. Here, too, the requirements are much more stringent than for aircraft turbines, since completely different fuels are used. The steels for the rotors, turbine housings, and gas ducts must likewise be selected most carefully on account of the high and varied stresses to which these parts are exposed. Scaling-resistant chromium steels often show a pronounced tendency to embrittlement. When used in combustion chambers they are in addition exposed to corrosion by oxidation and oil residues. Apart from heat resistance, good mechanical properties such as machinability, weldability, forgeability and bendability are, of course, indispensable in practice.

The gas turbine was introduced in iron and steel works at an early date. Its first use was that of an auxiliary engine for the Brown Boveri Velox steam generator. Gas turbines working at temperatures of 500°–570° C. proved satisfactory for this purpose, the working life in one case exceeding 70,000 hr. Experience has also been gained over many years with gas turbines, at a temperature of 500° C., used in oil refineries for the Houdry cracking process, combustion turbines for use at 500°–600° C. producing the air for blast-furnaces and and steelworks have also been brought on the market by Brown Boveri, and more are under construction, which seems to indicate that the combustion turbine will find interesting applications in iron and steel works.

THE SCALING BEHAVIOUR OF HIGH-STRENGTH HEAT-RESISTING STEELS IN AIR AND COMBUSTION GASES

By W. Stauffer and H. Kleiber, Dipl.Ing.

THE problem facing the metallurgist when determining the material suitable for the construction of gas turbines is that steels are required which possess as great as possible a high-temperature resistance to mechanical stress and to chemical attack. Any investigation of the chemical resistance of the steels must be carried out in co-operation with the designer of the gas turbine, so as to co-ordinate the various requirements.

In the investigation described in the present paper, the analyses of the steels tested are given in Table I and the composition of the combustion gases used in Table II. Steels Nos. 1, 2, 3, 4, 5, 6 and 7 were tested in air at temperatures of 600°, 700°, 800°, 900° and 1,000° C.; Nos. 1, 2, 3, 6 and 7 were tested in combustion gases I and II at temperatures of 600°, 700°, 800° and 900° C., and in combustion gas III at 1,000° C.

Steels Nos. 4 and 5 were not examined in combustion gas, since they suffered comparatively great scaling losses even in air. Steels 8 and 9, however, were studied in addition in air and in all three combustion gases at 750° C.

The test results are indicated by curves, and it is noteworthy that some of the curves intersect each other, and that, in some cases, the high-sulphur combustion gas causes less scaling than that with a low sulphur content. Phenomena of this kind are presumably due to the great scatter of the test results. As a general rule it is found that at low temperatures, up to 600° C., and in some cases up to 700° C., the sulphur content has no appreciable effect on the scaling loss.

It is interesting and unexpected that according to the tests, 25/20 type steels are less sensitive to the effect of sulphur than 18/8 type steels, and further, that the martensitic and ferritic 17/1 chromium-nickel and 27/4·5/1·5 chromium-nickel-molybdenum steels are not superior to the ordinary chromium-nickel steels. This is in contradiction to the opinion expressed frequently that the former are more resistant.

The authors state that this investigation gives information regarding the behaviour of some steels studied in 120-hr. laboratory tests interrupted four times by intermediate cooling. It must be borne in mind that it is not justified to transfer the results immediately to the behaviour in practice, since scaling does usually not increase linearly but parabolically, becoming slower with time. The scaling to be expected in practice can thus not be determined reliably on the basis of laboratory tests of this kind.

JOINT DISCUSSION

The President (Dr. C. H. Desch, F.R.S.), referring to the paper by Dr. Sykes, said that this was the Second Hatfield Memorial Lecture, and dealt with a subject in which a very prominent part was played by the late Dr. W. H. Hatfield, so that when it was decided to establish in Dr. Hatfield's memory a biennial lecture on some metallurgical subject it seemed very appropriate that one of the first lectures should deal with steels at high temperatures, and that it should be given by Dr. Sykes, who succeeded Dr. Hatfield as head of the Brown-Firth Research Laboratories.

Mr. C. C. Conway (The Mond Nickel Co., Ltd.) said that the papers contained a wealth of detail on the properties of high temperature materials. These data, when carefully considered, might help the engineer in his difficult task of designing heat engines, but without due consideration his task might well be all the more difficult. At the present time, the engineer wished to make use of materials which could operate for long periods of time at temperatures above 600° C. In order to do that it was necessary, as the authors had pointed out, to make as full a use as possible of the data to be provided by laboratory experiments. At the same time, the engineer must not allow himself to be misguided by data which were not strictly applicable. While laboratory experiments could give indications of future behaviour, there could be no short cut; only by the results of service trials over long periods, coupled with full details of running conditions on materials chosen on the basis of reasonable and well-planned laboratory experiments, could the answer be found.

Here he wished to differ radically from the statement made by Zschokke and Niehus; there was not, in his opinion, any theoretical basis for extrapolation of creep behaviour into the future. The double logarithmic method adopted in two of the papers presented that morning could lead to grievous error, and should be treated with great reserve.

Zschokke and Niehus were right to draw attention to the possibilities of structural change, which might have disastrous effects in a turbine installation. The evidence of change and deterioration must, however, be sought in the material itself, and not in data plotted on an artificial basis.

In criticising the double logarithmic plot, he said that in his experience it did not give straight lines, and one would not expect it to do so. He would recommend that if on a stress/log time plotted data there was definite evidence of progressive declination from the straight line outside the scatter band and towards the abscissa, then the quality of the material used in those tests should be examined exhaustively at the end of the test. That did not preclude examining the materials in any case.

To some extent his remarks on the validity of laboratory experiments applied to the paper by Stauffer and Kleiber. The conclusions, as the authors pointed out, were somewhat at variance with the general picture of the behaviour of the steels in question under such conditions. The apparent inhibition of attack by the presence of high sulphur had, he believed, been noted before in a catalytic plant under alternating oxidising and carburising conditions, and might be due to the prevention of carburisation.

Mr. D. A. Oliver (William Jessop & Sons, Ltd.) said that there was one point on which he differed slightly from Dr. Sykes. He was rather more optimistic than Dr. Sykes about the solution of some of the difficulties relative to the higher alloyed steels for operation at the higher temperatures. In some recent work which they had undertaken they had, to their great satisfaction, found that the alloy segregation in some of the very complicated highly alloyed steels was surprisingly small as measured by taking an ingot, sectioning it, drilling it at different points and considering the gradient in alloy concentration.

In dealing with very large rotor forgings it was wise not to take them up to the highest solution temperatures, and in cooling, which was often air cooling, the position again was not so bad, because if the centre cooled more slowly and was virtually tempered after solution treatment the properties observed in consequence of that were that the maximum stress and the proof stresses increased and the creep resistance decreased only slightly.

Referring to the excellent paper by Zschokke and Niehus, they were very much indebted to the authors for

pointing out the tendency for serious σ phase formation which was recorded in one of the illustrations. That information was not generally known in Great Britain until the authors tackled it, and some recent work with which he had been concerned corroborated it absolutely perfectly. There seemed to be a limit round about 22–23% chromium in the steel under consideration above which one did run into some degree of σ phase formation.

Finally, with regard to the paper by Stauffer and Kleiber, the subject which they had outlined, and which they admitted was only early work, helped to balance the series of papers presented very well.

Mr. J. T. MACKENZIE (United States Steel Export Co.) said he had just seen the data presented regarding the σ phase, but in the experiments in their steel laboratories at Pittsburg on stainless steel they found that the σ phase could occur in austenitic steels with as low as 18% chromium. It was generally in the combination of the higher molybdenum type of austenitic steels, but there had been repeated cases of 18% or 19% chromium with nickel—the 18/8 type of steel—which showed σ formation on exposure to high temperatures, and the evidence indicated that it formed from the ferrite phase which was present due to the unbalanced nature of the alloy. On the other hand, experiment at the Carnegie Institute of Technology had shown that the σ phase could form directly from austenitic material, so that it was not possible to be absolutely sure that there was any lower limit in the chromium content in σ formation, as long as one had either ferrite formers or σ formers of the nature of molybdenum. That was a word of caution for high-temperature steels, because molybdenum was a familiar alloying element, and with high molybdenum types there seemed a definite tendency for the formation of σ phase even with very low chromium contents.

Dr. T. P. HOAR (Cambridge University) said he had listened with very great interest to the two papers on the high-temperature resistance of steels based on the chromium-nickel type, and agreed with the previous speaker that a great deal of caution was necessary in connection with the formation of σ from modified chrome-nickel steels, particularly as the modifications which were made to improve scaling resistance and also creep resistance at high temperatures were the addition of molybdenum and also of silicon. The previous speaker had emphasised the influence of molybdenum in leading to σ formation even in steels of low, or comparatively low, chromium content. It was also very likely that silicon was a σ former, and in some work which had not yet been published they had evidence that in a really very low chromium steel, containing less than 17% chromium, but with additions of the order of 3% molybdenum and 2·5% silicon, σ formation could take place very readily in the range referred to. It was very unfortunate that the σ embrittlement occurred, because there seemed to be some evidence, perhaps of a rather tentative nature, that to far as scaling was concerned the formation of σ was no disadvantage, and might even give rise to a slight improvement.

Mr. W. E. BARDGETT (The United Steel Companies, Ltd.) remarked that in Dr. Sykes's very interesting paper a statement is made that he carried out accurate measurements of the variation in length of unstressed specimens, exposed at 650° C. and showed that contractions of up to 0·1% could occur, depending on the prior treatment. They themselves, Mr. Bardgett said, had confirmed that changes in dimensions of the same order were obtained in certain high alloy steels, and it would be of interest if Dr. Sykes would say how far he took into consideration such dimensional changes in the unstressed condition when considering material which was being tested under creep conditions.

The work carried out by Zschokke and Niehus on the effect of cold work on creep was of particular interest, but the results given referred to relatively short periods of test. It would be interesting to know to what extent the results were modified by longer periods of testing. While cold or warm work might improve the creep resistance, it was possible that, as was pointed out in the paper, over-ageing might be unduly accelerated. Whilst that expedient had been resorted to in materials for aircraft, where the true and total effect of the warm work could be evaluated, it was of questionable value when materials were subject to service during periods beyond the normal range of testing. In either case the aim should be to provide materials which would give the desired properties without warm working, since the latter was open to the objection that it was not readily controlled and that the same optimum degree of work might not be possible for the components as a whole, and that a suitable method of selection of specimens might be difficult.

The work carried out by Stauffer and Kleiber was very valuable. He himself had had in mind the point which Mr. Oliver had so well brought out. He thought that it was not possible to expect a consistent differentiation between steels and scaling tests when the degree of scaling was quite small, and one would rather group them into the range of temperature where the material did not show a marked increase in scaling. It would be interesting if the authors could include some photomicrographs to show the form of attack on the materials in the presence of different amounts of sulphur.

Sir WILLIAM GRIFFITHS (The Mond Nickel Co., Ltd.) took advantage of the opportunity provided by the discussion of Dr. Sykes's paper, to pay a tribute to the contribution which the late Dr. Hatfield made to the subject of high-temperature alloys. Dr. Sykes had described what Dr. Hatfield did himself, but personally he would like to emphasise the encouragement which Dr. Hatfield gave to others who were working on the subject, and the stimulus which his work provided for further advances.

It had been his own good fortune and that of his organisation, Sir William said, to be involved in this question early in the recent war, and the target at which they had to aim, and which they had if possible to exceed, was that which had already been set up before by Dr. Hatfield and his organisation.

The other point was that if advances were to be made in this subject it would be necessary to take risks. The tendency of a technical body was perhaps to emphasise the difficulties of transferring the results obtained in the laboratory into practice and to point out all the difficulties involved in getting a proper assessment of the materials by laboratory measurements. He would be the last to decry the importance of those tests, but, when one considered the time involved in any creep test or long-time fatigue test at high temperatures, and the very many variables involved in any material which was being considered and in the test procedure, then if it was necessary to wait for absolute certainty, as indicated by the various curves obtained, he feared that the development of the gas turbine might have to wait a long time.

He suggested that they should go ahead with practical tests as well as with laboratory experiments, and make use of that great standby of the engineer, the factor of safety, which gave that experience which had now been built up

TABLE I.—ANALYSES OF THE STEELS TESTED

No.	C, %	Si, %	Mn, %	P, %	S, %	Ni, %	Cr, %	Mo, %	Ti, %	V, %	N_2, %
1	0·05	0·50	0·35	0·025	0·025	8·5	18·0	—	—	—	—
2	0·10	2·35	1·25	0·03	0·03	11	20·0	—	—	—	—
3	0·20	2·47	1·06	0·03	0·006	20·3	24·17	1·57	—	—	—
4	0·15	0·75	16·0	0·025	0·025	—	14·00	—	—	—	—
5	0·08	0·50	0·60	0·025	0·025	—	13·50	—	—	—	—
6	0·22	0·50	0·35	0·025	0·025	0·8	17·00	—	—	—	—
7	0·17	0·38	0·17	0·025	0·025	4·5	25·80	1·58	—	—	—
8	0·15	3·00	17·0	0·06	0·025	1·75	9·00	—	0·5	—	—
9	0·07	0·75	18·45	0·003	Trace	0·44	12·00	—	—	0·70	0·1

in the steam turbine field, and which it was hoped might bring about in the same way quite a large use of the gas turbine with the use of materials which, if they were not already available, he felt sure would be available by the time that the engineer required them.

Dr. SYKES and Mr. STAUFFER intimated that they would reply to the discussion in writing.

Mr. K. H. NIEHUS, in reply, agreed with Mr. Conway that the utmost care must be taken to prevent any errors in the testing apparatus coming into the judgment of the behaviour of the steels, and also that care must be taken to see that the temperature measurement was accurate, although in that case it was necessary to bear in mind that the temperature was not absolutely constant in the machine, so that if a steel was very sensitive to a temperature change of a few degrees only, or even of 10°–20°, it would not be much use in an actual machine. He also agreed that an extrapolation from a few hundred or a few thousand hours to 100,000 hours was very unsatisfactory, but he did not think that the extrapolation in a double logarithmic scale was any worse than an extrapolation in a linear stress/log time scale. They pointed out in the paper that for certain steels that had actual running experience for long periods, and they had to balance that against the short-time tests. For high temperatures and new alloys that experience was not yet available, and there they had to take a step into the unknown, and whether any extrapolation would help or not could be decided only by experience.

He agreed absolutely with what Mr. Oliver said about cold working. What Mr. Mackenzie had said about the σ phase was very interesting, although unpleasant. Personally, he was inclined to believe from recent tests and experience that the σ phase would occur even at 18% chromium.

The question of what degree of embrittlement was still permissible in steels for combustion chambers was easy to answer. Embrittlement was possible as long as the lining of the chamber would stand up to the work without cracking. They could not give actual figures, because very little was known about the stresses in the combustution chamber due to thermal expansion. The question of corrosion fatigue strength must be investigated, because very little was known about it at high temperatures.

TABLE II.—COMPOSITION OF COMBUSTION GASES

Components	Combustion Gas I (S = 0·05% in Fuel Oil)		Combustion Gas II (S = 0·5% in Fuel Oil)		Combustion Gas III (S = 5·0% in Fuel Oil)	
	Wt.-%	Vol.-%	Wt.-%	Vol.-%	Wt.-%	Vol.-%
CO_2	22	14	22	14½	21·5	14·2
H_2O	7	11½	7	11½	7	11·5
SO_2	0·007	0·003	0·07	0·03	0·7	0·32
N_2	71·0	74·0	71·0	74·0	70·8	74·0

New Method of Making Steel Direct from Ore

EFFORTS have frequently been made to eliminate the blast furnace in the manufacture of steel, but, until recently, little success has been achieved. Before the war experiments were carried out in the Soviet Union that fielded interesting results. More recently work has been resumed, and according to Ivan Bardin iron and steel works in the south can now look forward to obtaining high-quality steels in open-hearth furnaces direct from ore. It is claimed that the method developed can yield a number of mild steels for various purposes. Such steel has been made and put through a tube-rolling mill and the tube produced proved to be of good quality, withstanding all the usual tests.

Professor Bardin emphasised that the new method, which he did not describe, presupposes a supply of high-quality raw material. The Krivoi Rog Basin possesses natural pulverised ore containing 68% iron and only 2% silica. Ores with such a high percentage of iron are most suitable for the new process.

Experiments in smelting steel by the new method are being continued at a plant in the south, and a series of melts has shown that from the technical point of view this problem is meeting with satisfactory solution.

The economic value of a successful method cannot be over-estimated. Everybody will appreciate the benefits to be derived from eliminating the extremely laborious and expensive blast-furnace stage. The Central Institute of the iron and steel industry of the U.S.S.R plans to devise an open-hearth furnace of a special design for the new process. The task that still faces Soviet experimenters, however, is not only to prove the technical feasibility of the new process, but make that process highly economical.

The Ferex Electrode

A recent addition to the range of electrodes manufactured by Murex Welding Processes Ltd. is the "Ferex" electrode, which is a special ferretic type designed to supplement austenitic electrodes for the welding of tank armour.

Recently, these weldability characteristics have been improved and its applications widened. It is outstanding in its ability to minimise hard zone cracking in high carbon and alloy high tensile steel, consequently thicker plates and more difficult steels can be welded than was possible previously, e.g., this electrode is invaluable as a pre-coating layer on steel rails especially composite rails, and furthermore has shown promise in welding crane rails to stanchions. In maintenance work it is an ideal type since, in many cases, it obviates the need for pre-determining the analysis of the steel to be welded.

The weld metal is very free from non-metallic inclusions and the mechanical properties are excellent especially under notch and brittlement conditions. Its Izod value is maintained to a low sub-normal temperature thereby enabling the electrode to be used in applications working at −45° C. to −70° C.

"Infra-Red" Heating by Gas—Its Development and Practice To-day

By J. B. Carne, B.Sc.

Appliances to effect heat transfer now cover a range of temperatures from 10° F. for refrigeration to about 3,400° F. for metal treatment. But the process of evolution in design continues and new appliances appear either embodying improvements on existing practice or using a new technique. Infra-red appliances have been developed to meet a distinctive industrial heating technique. This technique and some fundamental qualities of infra-red are discussed. Particular attention is directed to infra-red equipment in practice.

The Application Range of Heat-transfer Appliances

THE countless variety of gas appliances devised and employed for domestic and industrial uses since some 130 years ago, when the district supply of coal gas began, can be classified under headings which are descriptive of the modes of heat transference by which the appliances are effective—i.e., convectors, radiators, conductors and convector radiators. In each type the heat energy is initially available at the point of combustion in gases at temperatures in the region of 3,000° F.; the actual temperature being dependent on a number of factors, important amongst which are the composition of the gas, the method of combustion, and the degrees of premixing and preheating of the gas and air.

The way in which this heat energy is dissipated from the hot gases is governed by their temperature and their environment. Even in the case of a freely burning flame it is not possible to state precisely in what proportions of convection and radiation this available heat is dispersed. The following table, however, conveys some idea of these proportions before they are modified by design of the appliance to effect a high efficiency of utilisation, and it will be noted that in each kind of flame only a minor proportion of the heat of combustion is available as radiation.

TABLE I.—DISSIPATION OF HEAT FROM FREELY-BURNING COAL GAS FLAMES IN SURROUNDINGS AT 60° F.

Type of flame	Gas pressure at jet in inches of water	% of heat of combustion, dissipated as :— Radiation	Convection
Pre-aerated—Bunsen type			
Ordinary low pressure ..	3 in.	11·5%	88·5%
High pressure	81 in.	6%	94%
Gas jets—Flat flame type			
Batswing	0·3 in.	11%	89%
"Neat Gas"	3 in.	4%	96%

The functional requirements of appliances for various purposes have naturally resulted in designs in which the heat of combustion, initially available as indicated in Table I, is converted into forms better suited to the desired application, and thus to-day we have appliances such as air and water heaters in which 80% of the heat in the gas burned is convected in the heated air or water, and radiant heaters such as domestic fires in which up to 55% of the thermal value of the gas is available as radiant heat, and conduction heaters such as platens and domestic irons in which 50–60% is transmitted to the work by contact with the appliance.

This range of appliances, the development of which has entailed an enormous amount of experimental work, both in the laboratory and in the domestic and industrial fields of utilisation, now covers equipment to effect heat transfer at temperatures from 10° F. for refrigeration, to about 3,400° F. for metal treatment. Even so the process of evolution in appliance design continues and new appliances appear, either as improved models to meet the needs of existing practice or as apparatus to enable the operation of a new technique in industry. "Infra-red" apparatus falls into the latter class of new appliances for they have been developed to meet, what has become during the past 14 years, a distinctive industrial heating technique.

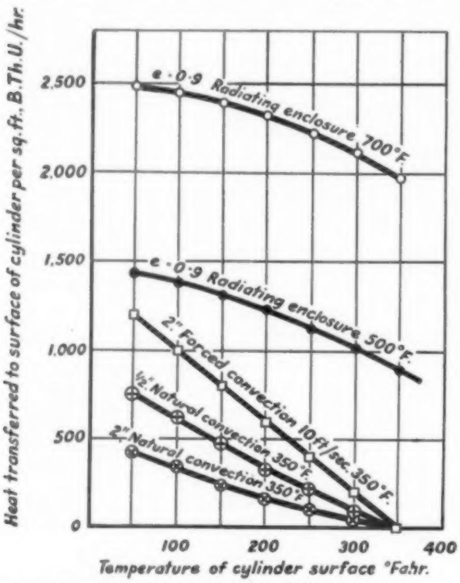
The Evolution of the "Infra-red" Technique

It might with justification be asked, "How is it that after more than a century of practical application and intensive development of gas equipment to cater for processing at temperatures throughout a range of some 3,000° F., only now a new technique appears?"

To the writer the explanation lies in the fact that until comparatively recently it had not been fully appreciated, in manufacturing industry, that the convection and radiation by which heat is transferred to an article in an oven are quite independent phenomena governed by totally distinct physical laws, and that the part which each plays can be to a large extent controlled by design. Even in recently published authoritative studies in heat transfer, formulæ are met in which a single expression is used to account for both the radiation and convection transfer from a body; this despite the fact that the mechanism of convective transfer as distinct from radiation was recognised more than 160 years ago by Count Rumford in the course of a scientific investigation into the insulating values of clothing materials. There has been, of course, amongst designers in many branches of engineering where heat transfer is important, appreciation and exploitation of the principles involved and much research work on the measurement of convective transfer, by both natural and forced flow, has been made—particularly in the case of the latter. It remained, however, to the organic chemist, using heat transformable paints to demonstrate, indirectly but convincingly to the process engineer, the greater speed of heating which radiation can effect as compared with convection methods. Some such paints when raised to about 400° F. harden within a few seconds, and thereby make evident the heating effect of the system used. The rates of transfer of heat at oven conditions normally employed, are shown graphically for comparison in Fig. 1.

The initial application of "infra-red" to industrial processing is attributed to the Ford Motor Co., who in 1933 employed electric incandescent filament lamps for stoving car bodies, but it was the desperate urgency for

speed in production during World War II which established its practice. By then industrial paint manufacturers were able to supply on a commercial scale, synthetic resin paints designed to cure rapidly at elevated temperatures, and these were available for the protective finishing of war service equipment. For this purpose electric and gas "infra-red" units found many successful applications, the former particularly in the aircraft industry and the latter for the treatment of the heavier fabricated metal components. The results with such installations, one of which is seen in the photograph of Fig. 2, were such an advance on those hitherto achieved with convection systems that those responsible for production could hardly fail to be impressed with the capabilities of "infra-red" for mass production



2 *in. dia. cylinder, "near black" finish*
○ Radiation Walls, 700° F.
● Radiation Walls, 500° F.
□ Forced convection 10 ft./sec., 350° F. air temp.
⊗ Natural convection, 350° F. air temp.
½ *in. dia. cylinder*
⊗ Natural convection, 350° F. air temp.

Fig. 1.—The rates of transference of heat by radiation, forced convection and natural convection.

So spectacular were the effects obtained with the combination of thermo-setting resin paints and "infra-red" systems that the "abra-cadabra," so easily linked with a scientific term such as "infra-red," became associated with the process, and such terms as "catalysis" and "selective response"—suggesting some kind of resonance effect between the radiation and the resin molecules—were used in explanation. Certainly these views confused the real explanation, for had the problem been recognised as being, except in special cases, one depending solely on the temperature-time cycle to which the material processed is subjected, and consequently a normal problem of heat transfer in which convection as well as radiation plays its part, it is hardly likely that so many "infra-red" ovens in which the air temperature was allowed to remain little above atmospheric temperature would have been put into service. Certain defects in processing by "infra-red," which arose in practice due

(Courtesy of Pearce Signs, Ltd.)

Fig. 2.—A war-time installation of gas-fired "infra-red" unit panels for the rapid stoving of transformer cases and components. The capacity of this oven was increased to stove larger articles for peace-time production, by the simple addition of more unit panels.

to lack of a full understanding of the physical factors concerned, forced a more rational consideration to be given in both the design and operation of equipment and to-day it is realised that successful and economical application of "infra-red" necessitates the minimisation of the convective loss from the articles processed by maintaining an elevated air temperature in the radiation zone.

Gas "Infra-red" Units

There has been much criticism of the use of the term "infra-red" to describe what is nothing more than the already and more easily understood term "radiant heat." Although from this point of view there is little justification for its use, it has the advantage of implying a technique of heating in which the transfer is mainly effected by radiation of moderate intensity, which can be provided by sources maintained below incandescence temperatures. Such intensities can, of course, be also provided by highly incandescent radiators of small area, and both electric and gas units of this type are available to industry. Most of the American pattern gas "infra-red" units, for instance, the "Red-ray" and the "Burdett" burner* and the Selas "cup burner," are of this type, but industrial practice in this country has demonstrated conclusively that suitably designed non-luminous radiators are entirely adequate for the "infra-red" range of processing and at the same time are highly efficient and durable under industrial conditions, features which are essential to economical production and result mainly from the moderate temperatures of operation. Two principle features are common to the British "infra-red" units specifically designed for industrial processing, firstly, a high proportion of the heat of combustion is transformed into available radiation by causing the flame

* Described in METALLURGIA, March, 1947.

gases to raise the temperature of a metal sheet or plate which then becomes the source of radiation, and secondly the flue gases from the unit are normally discharged outside the heating zone. Departure from this last mentioned practice is in some processes very advantageous, considerable economy being effected by utilising the heat in these gases.

Some Fundamental Qualities of "Infra-red"

Besides the greater speed of heat transfer by radiation compared with that attained by convection, a further advantage of great importance in processing is that because of its direct propagation radiation is more easily controlled in application than is convected heat. Provided, therefore, that adaptable radiating units are available and correctly applied, process heating can be effected not only rapidly but with a high efficiency of utilisation.

In the heat-treatment of materials which are partially transparent to radiant heat, such as glass and certain organic plastics, heat is developed at depth below the surface on which radiation is incident, and thus more uniform as well as more rapid heating of the bulk of the material is effected than by convection heating since the latter is invariably by superficial absorption.

To gain this advantage of radiation, especially useful when the material is a poor conductor of heat, it is essential that the radiation used is of a wavelength to which the material is partially transparent, for no absorption and therefore no heating effect can result from the use of radiation to which the material is perfectly transparent, and no penetration would occur in the case of perfectly opaque materials, such as the metals. In production practice it is not often that this particular attribute of radiant heat can be exploited ; but where it can, it is necessary to match as far as is practicable the spectral quality of the radiation which the spectral absorption characteristics of the material. Particularly useful in view of the growing use of plastics are measurements of the transmission characteristics of many of commercial importance, which have been made by the Gas Research Board.[1]

More important, where metallic objects are subject to heating, is the degree of reflectivity for the radiation incident on the object, since "rejection" of the radiation may be as high as 95% as in the case of polished steel, copper or aluminium, or as low as 5% in the case of a black painted surface. Here too, since the degree of absorption or reflectivity may vary with wavelength of the radiation, attention to the suitability of the radiation used is necessary in order to avoid processing difficulties. The differences in absorptive power of various paints due to colour, vary from a practically negligible degree with the longer wavelength "infra-red" radiation emitted by the medium temperature sources operating at below red incandescence to a serious degree with the short "infra-red" of the near visible wavelengths characteristic of high temperature sources emitting a good proportion of visible light. Temperature differences of 80° F. entirely due to colour difference of paint on sheet metal irradiated with electric incandescent lamp radiation were noted by Maxted.[2]

In view of the dependence of the heating effect of radiation on surface finish it is evident that in measuring the "heating-np" rate of an article during its exposure in the "infra-red" zone it is essential that the article is coated with the material as it would be in the actual processing. The importance of this point is shown clearly by a comparison of the time temperature curves, Fig. 3, of heavy gauge steel.

(*a*) Cleaned and with a bright finish ready for painting.
(*b*) Coated with red enamel paint.

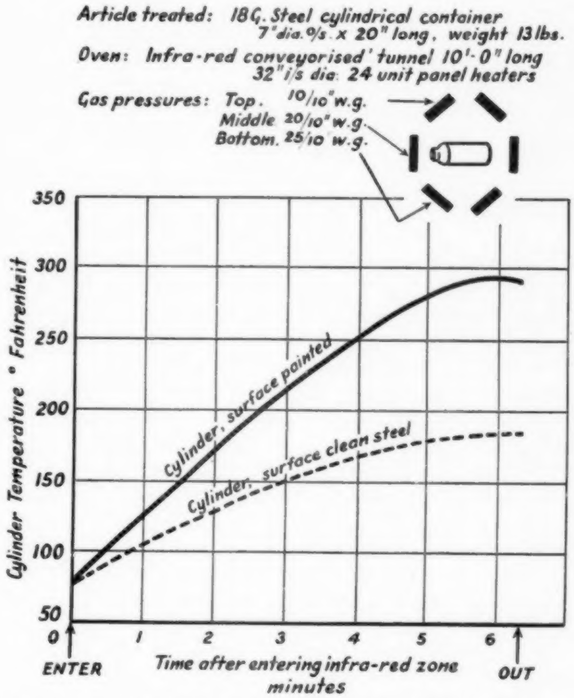


Fig. 3.—The effect of surface finish on "heating-up" rate.

The curves of Fig. 3 also show clearly the unsuitability of radiant heating, alone, for the rapid heating of materials with highly reflective surfaces, such as required in the annealing of aluminium or heating of plated and polished articles. This conclusion does not, of course, rule out the use of high-temperature oven interiors in order to create high temperature air convection effects.

Subsidiary Advantages of "Infra-red"

The considerable reduction of processing time which results from the substitution of "infra-red" for convection methods, often amounting to 80%, may permit many other economies to be effected in the production system and workshop layout.

Thus a five-minute stoving period for paint may enable a production system to be fully conveyorised, owing to the relatively small space occupied by the "infra-red" oven in comparison with that for the equivalent convection oven. Again the speedy drying of adhesives, paints and moisture, which may allow the articles to be stacked for transport or storage, or handled for an assembly operation, within a few minutes of pre-treatment, often results in a great saving in factory space otherwise occupied by equivalent convection ovens or by the articles while drying under atmospheric conditions.

Quality of finish of a painted surface may be better because with "infra-red" the period of the tacky state is shorter and the dispersion of dust in the heating zone

1 "Industrial Gas"—*Gas World Supplement*, Dec. 15th, 1945, p. 140.
2 . Maxted. *Transactions Ill. Eng. Soc.* (London), 1942, Vol. VII, p. 10.

is less than in ordinary and forced convection ovens, factors which considerably reduce the probability of dust adhering to the coated surface.

Instances have occurred where by the adoption of " infra-red " it has been possible to dispense with special holders for painted articles, found necessary to minimise the flow of paint during the long period it remains fluid when stoving in the slower convection oven.

The greater speed and the higher temperatures attained with " infra-red " may however introduce undesirable effects unless a rational design of " infra-red " equipment is adopted which allows for all the factors in the heat-transfer problem.

The Complete Problem of Heat-transfer

Simultaneous with the absorption of heat by radiation in the " infra-red " oven indicated by the curves of Fig. 1, there occurs transfer by convection—mainly a loss of heat from the article—which increases as the temperature difference between the article surface and the ambient air increases, and which varies in a complex way with the shape and dimensions of the surface—generally speaking, being at a rate per unit area which is greater the smaller the article. General reference to convection effects in "infra-red" ovens was made in some early papers on the subject, particularly by Tiller and Garber,[3] and the significance of the variable convection loss in respect to uniformity of processing and the consequent importance of a high air temperature in the " infra-red " zone have been discussed in some detail elsewhere[4, 5] by the writer. Inspection of the appropriate heat-transfer curves in Fig. 4 for temperature conditions commonly prevailing in " infra-red " ovens, will show that at low air temperatures the convective loss may be sufficient to prevent the attainment of a temperature adequate for processing, a condition, as already mentioned, more readily established with articles of small dimensions. An elevated air temperature not only practically avoids this defect but tends to eliminate shadow effects and temperature differences due to variation in absorption characteristics.

Convective and radiant transfer are both surface effects, except in the special cases noted where the material concerned is semi-transparent to the radiation, and thus generally the temperature of a thin section article, that is one with a small heat capacity per unit surface area, will rise more rapidly than that of a thick

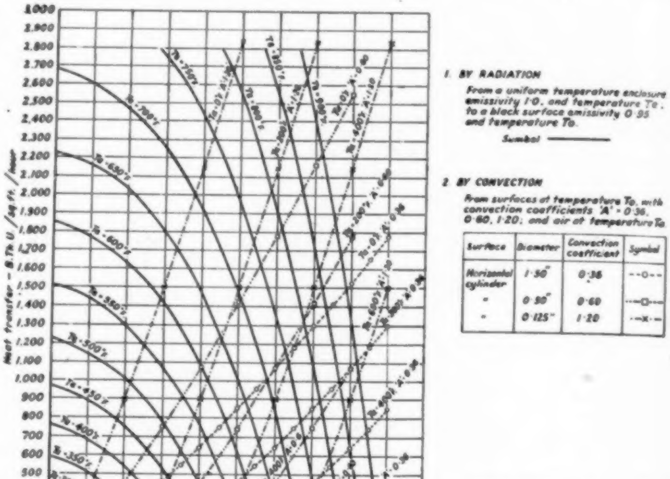


Fig. 4.–Heat transfer by radiation and convection between surfaces and surroundings.

article exposed to the same intensity of convective and radiant heating. Increased speed of processing, whether achieved by higher convective or radiant transfer conditions, enhances such differences, but due to the greater control in the case of radiant transfer it is often possible to effect a tolerable degree of uniformity of processing at high speed by a suitable distribution of radiation.

It follows from the main factors described in this broad outline, that it is desirable that an " infra-red " system should provide a high air temperature in the heating zone and should be capable of establishing an adequately variable field of radiation.

To be continued

3 F. M. Tiller and H. J. Garber. *Ind. Eng. Chem.* (1942), 34, p. 773.
4 J. B. Carne. *Sheet Metal Industries* (1945), 22, p. 175.
5 J. B. Carne. Paper to Amer. Soc. Mech. Eng. N.Y., Dec., 1946. *Fuel*, Sept., 1947.

Heat treatment Plant for India

We understand that G.W.B. Electric Furnaces, Ltd., of Dudley, Worcs., have obtained the contract for a complete heat-treatment plant for the motor-car manufacturing factory of the Hindustan Motors, Ltd., at Calcutta, where the " Hindustan " cars will be made.

The carburising section consists of a number of Gibbons-Wild-Barfield batch-type furnaces served by a Gibbons' van, Marle, electrically operated charging machine. Wild-Barfield " Heavy-Hairpin " horizontal and vertical batch-type furnaces will be used for reheating and hardening, whilst vertical forced air circulation furnaces, equipped with the patented charge progress recorder, will cover all tempering operations. For cyanide hardening and the heat-treatment of high-speed steel tools, the standard Wid-Barfield electrode salt baths are being supplied.

Who Wants More Orders?

A Birmingham firm of repute who is engaged in the marketing of huge quantities of ex-Government stock, has available a large sales' organisation controlled by experts who have bought and sold miscellaneous merchandise to the value of many millions sterling.

Any manufacturer who wishes to devote his energies exclusively to production and to relegate the distribution to a separate undertaking is invited to send details of any specialities in popular demand that can be sold in large quantities direct to the public by mail order or other general publicity methods. Substantial supplies of suitable lines will be bought outright regularly and sold direct to the consumer for manufacturers who contact Haviland and Company, 1, Rutland Road, Bearwood, Smethwick.

Symposium on Powder Metallurgy

Hard Metal Carbides

A symposium on powder metallurgy was presented at a recent meeting, organised by the Iron and Steel Institute, and held in the lecture theatre of the Institution of Civil Engineers. It comprises 28 papers and is divided into sections each dealing with different aspects of the subject. In this review attention is directed more particularly to section D which concerns hard metal carbides.

A SYMPOSIUM on powder metallurgy published as Special Report No. 38 was the subject at a recent meeting, organised by the Iron and Steel Institute, which included members of the Institute of Metals, the Institution of Mechanical Engineers, the Institute of Electrical Engineers, the Institute of Production Engineers, the Institute of Automobile Engineers, and the Society of Chemical Industry. Three sessions were held at which the various papers were presented for discussion.

The symposium is divided into six sections: the first being of an introductory character deals with powder metallurgy in Great Britain; Section B is concerned with the preparation, properties and testing of metal powders, and compresses four papers; Section C is on magnetic powders and products and consists of five papers; Section D deals with hard metal carbides and different aspects are discussed in four papers; Section E is concerned with porous metal components on which there are three papers; and Section F, which contains eleven papers, deals with the manufacture and properties of sintered components. This report is comprehensive and an idea of this may be gathered from the four papers in Section D with which this review is mainly concerned.

The Preparation of Carbides

In the first paper of this section Mr. L. D. Brownlee, Mr. G. A. Geach and Dr. T. Raine discuss the methods used for the preparation of carbides and double carbides of tungsten, describe titanium and tantalum, and give manufacturing details. Tantalum carbide is only used occasionally in this country, up to 5% additive, and to a much less extent than in the U.S.A. Small additions of vanadium carbide were used in Germany; and molybdenum carbide was at one time the major constituent of a special brand of hard-metal which is apparently no longer used, though it is mentioned in some recent French patents. Niobium carbid also has been prepared, but, according to the authors it is not yet used on a commercial scale. The three first-named carbides (of W, Ti and Ta) are all interstitial types of compounds existing over a restricted range of composition; and, in a protective atmosphere, they are stable over a wide temperature range. They have very high melting points and are therefore prepared by diffusion methods.

Single carbides are produced by: (*a*) Direct carburisation of the metal powder by carbon; (*b*) combined reduction of oxide and carburisation; or (*c*) carburisation of an alloy followed by chemical separation; and double carbides by heating mixture of: (*a*) Individual carbides; (*b*) oxide, carbide and carbon; or (*c*) two oxides and carbon. The preparation of the carbides of tungsten, titanium, tantalum and of some double carbides is described in detail, as also is the preparation of final mixed powders. Furnaces of the h.f. induction and vacuum carburising types are described and illustrated. Any form of carbon powder having low ash, volatile matter and moisture contents can be used, but lamp black or carbon black is preferred. The heating must be done in a pure hydrogen atmosphere. In the final mixed powders from 4·5–25% cobalt as powder is incorporated, and mixing and milling are combined in one operation in ball mills.

The Manipulation and Sintering of Hard Metals

In his paper on the manipulation and sintering of hard metals, Mr. H. Burden describes the main stages in the production of a consistent high-quality hard metal from prepared powders—namely: pressing, presintering, shaping and final sintering, for the tungsten carbide/cobalt group and the titanium carbide/tungsten carbide/cobalt group. Some of these operations may be omitted, depending on the type of pressing employed; but it is shown that care in manufacture and choice of suitable equipment may be quite as important in determining properties as large changes in composition. Pressing to finished shape is an advance in modern practice, and in the case of carbide pieces it is done on rapid acting hydraulic or pneumatic presses; control of dimensions being achieved either by pressing at a given pressure, or to a given density. For sintering, three types of furnace are mentioned: carbon-tube resistance, molybdenum-wire-wound alumina muffle, and the h.f., hydrogen atmospheres being used in the first two, and vacuum in the third. One of the most important aspects of sintering—control of carbon content—is discussed in some detail.

The Physical Metallurgy of Sintered Carbides

The important paper on the physical metallurgy of sintered carbides by Drs. E. J. Sandford and M. Trent is of both practical and theoretical interest. The authors state quite definitely that, although claims have been made in the patent literature for the use of nearly all the hard metal carbides, either singly or in combination, most of them have had no commercial success. Even in the case of tantalum carbide, largely used in the U.S.A., they consider there is no evidence to show that it is a worth-while addition, especially in view of its high cost.

But their paper deals mainly with basic principles and theory. The physical and chemical changes in cemented carbides during sintering are discussed, on the basis of contraction measurement and microscopical examination. Sintering commences before a liquid phase appears, but is not complete until some time after. The distribution, size and shape of the carbide grains

are determined by the sintering process and the constitution of the alloy system ; and the grain size of the cobalt-rich phase is shown to be considerably greater than that of the carbide. The appearance of other phases in alloys of tungsten carbide and cobalt in relation to carbon content and the tungsten-carbon-cobalt equilibrium system generally are discussed. If the theoretical and actual densities of cemented carbides are compared it is found that the porosity is very small. The more important physical properties and the effect of additions of titanium and tantalum are described. Special interest attaches to the theory of sintering presented and the various stages through which the pressed compact passes as temperature is raised. The strength, hardness, etc., of these alloys depends on a number of factors : the strength of carbide grains, of carbide-to-carbide grain boundaries, of carbide-to-cobalt grain boundaries, of the cobalt grains and of cobalt-to-cobalt grain boundaries. It is suggested that isolation of these factors and study of their separate effects would prove instructive.

The German Hard-metal Industry

The paper on the German hard metal industry is based on the relevant B.I.O.S. reports, copies of which are available from 37, Bryanston Sq., London, W. 1, The manufacture and use of iron powder in Germany. including diamond impregnated tools, based on BIOS 860 and 908, have already been described in this journal.* The present article in the symposium relates to hard metals, chiefly from tungsten carbide and substitutes, and to diamond-hard metal.

Tungsten carbide was prepared from ammonium paratungstate or tungstic acid, from which the powder was obtained by carbon reduction. Mixed powders were also produced containing titanium carbide. Some interesting mechanical developments, with illustrations of the appropriate plant, such as various types of furnace and grinding mills, are described in some detail. Shortage of tungsten in Germany as early as 1940 led to a search for substitutes, but despite much work in this direction, including other carbides such as those of molybdenum, vanadium and niobium together with nickel, no really effective substitute could be found.

The material known as diamond-hard metal consisted of a mixture of cemented tungsten carbide and diamond powder formed to the desired shape by hot pressing. It had a variety of uses, principally for grinding wheels and grinding wheel truing tools. Krupp was almost the only producer, though Kieffer made some for use in his own factory.

Cemented tungsten carbide was found most suitable as a bond for diamond-impregnated grinding wheels, for it satisfactorily fulfilled the two requirements : (*a*) Would not break or be worn away before the cutting capacity of the diamond particles was fully used up, and (*b*) did not " smear " or tend to load the wheel. A further advantage in the use of this bond was that its coefficient of thermal expansion closely approximated to that of diamond, so that there was less risk of the diamond particles loosening and breaking away due to heat generated. The chief use of diamond hard metal wheels was in grinding cemented tungsten carbide components, glass and similar hard substances ; and, owing to slow rate of wear, they were very suitable for form-grinding.

There was not enough hydrogen available for all the reduction processes, and so carbon was often used. The tungsten carbide obtained from Borchers carbon-reduced tungsten metal was employed by Krupp, with carbonyl nickel powder from I. G. Farbenind. The mixture consisted of 75% tungsten carbide and 25% nickel, and was prepared in the usual way. The diamond hard metal mixture consisted of 90% of this mixed powder and 10% of diamond powder of the desired grade, 20–40 μ and 10–20 μ, by weight ; and was prepared by hand-shaking in sealed glass bottles. Krupp considered the 10–20 μ grade the finest that could be satisfactorily used with the tungsten carbide bond. Finer powders should be bonded with phenolic resin plastics.

In making the diamond hard metal components, a special type of hot press with graphite mould was employed, using 100 kg./cm^2. pressure, and temperature outside the mould of 1,250° C., the time being about 2–3 mins. Temperature of the compact itself was 1,150° C., but max. temperature was only applied for about 20 secs. After pressing, the wheels were roughly cleaned up and ground to shape with silicon carbide wheels. Other compositions, such as Kieffer's were 5% TiC, 8% Co, and remainder WC ; also 2% TiC, 13% Co, and remainder WC, cold pressed and sintered at 1,500° C.

General hard-metal research in Germany.—The use of zirconium carbide and thorium carbide was studied in great detail by Kieffer, and showed that ZrC behaved like TiC in the formation of crystalline solid solutions with WC and Mo_2C, etc. The hardness of ZrC was about the same as that of TiC and WC. Thorium carbide has a non-metallic nature, and is unsuitable for cutting purposes.

Dawihl's researches on unsaturated carbide compositions for wire-drawing dies seem to support the view that the Widia Elmarid composition with 3% Co and 5% C depends for its peculiar properties on the presence of a phase (Co_3W_3C) formed during the sintering. For even distribution of this phase it is better to make the Co_3W_3C separately and then combine it with the balance of the Co and WC.

Kieffer and Hotop studied the structure of sintered hard metals of the WC/TiC/Co series by promoting excessive grain growth by prolonged sintering. With alloys containing up to 5% TiC a single carbide phase was present, being a solid solution of TiC in WC, and known as the mixed crystal phase. Alloys containing up to 25% of WC with 60–70% TiC also showed a single carbide phase, the mixed crystal, being a solid solution of WC in TiC. The results, which have been published, of this metallographic investigation from a valuable addition to the X-ray examination of the carbide system.

Some account is also given of the work done by Krupp's on the electrical and magnetic properties of hard metals, including magnetic saturation and coercive force measurements and conductivity. A special dilatometer was designed for studying shrinkage during sintering, and the electron microscope was used to examine the metal powders beforehand and for study of specimens at high temperatures. Effect of additions of chromium carbide was studied. Resistance to oxidation was one of the effects noted.

It is generally concluded that, although the Germans made no startling advances in the production of hard metals, they showed some ingenuity in designing efficient plant. Consumption of these products rose from 14

* June 1947 issue, page 106.

tons in 1934 to 500 tons in 1944; and it is thought that a substantial increase in the use of hard metal in the United Kingdom would improve industrial efficiency.

Special Report No. 38 is issued by The Iron and Steel Institute, 4, Grosvenor Gardens, London, S.W. 1. The published price is 16s. per copy. (To members of the Iron and Steel Institute and Institute of Metals the price is 10s.).

Some Effects of Welding Heating Cycles on Heat- and Corrosion-Resisting Steels

UNDER the above title in our last issue Mr. H. Bull considered the effect of welding on heat- and corrosion-resisting steels. He described the three main types—martensitic stainless steels, the ferritic stainless steels, and the austenitic stainless and heat-resisting steels—and discussed some of the effects of the welding heat on material adjacent to the weld. The effects of the welding heat were considered with respect to the changes in structure, corrosion-resistance, mechanical properties, etc., and some account was given of the metallurgical steps taken to overcome them. As previously stated, the paper was presented at a recent meeting of the North Eastern (Tyneside) Branch of the Institute of Welding from which some interesting discussion resulted. In view of the interest in this subject we give contributions to the discussion, together with the author's reply.

Discussion

Mr. J. G. M. TURNBULL.—I have listened with considerable interest to this paper which has contained so much useful information. If I may make a personal comment of a general nature, I think that this very excellent paper might have been improved to a gathering such as this, had more time been spent in explaining to the audience (who, I presume, are mostly welding engineers and not metallurgists), exactly the applications and effects of the various metallurgical features which have been shown in the paper. I know that it would have taken much longer time, and I may be all wrong, but I have a feeling that many of the more important observations may have been missed by people here who have not the metallurgical knowledge to assist them in relating the metallurgical phenomena to welding technique. The hardening of the ferritic steels by nitrogen was extremely interesting to me. Has the author any fundamental explanation to give of this phenomenon? It is obvious that 16% chromium steel, being close to the martensitic range, will harden more than those steels with a higher chromium content, but this extreme hardening due to the effect of nitrogen is rather remarkable. I am wondering whether the author has made sufficient progress in his investigations to give an explanation of it? From these results it would appear that such a steel would be rather dangerous to use for welding, and if the author is of that opinion, I think it should be stated for the benefit of people who might want to use such a steel.

Regarding austenitic steels, again we have these remarkable phenomena of hardening between 600° and 900° C. with the duplex steels, but as regards welding, does the author think that this really can produce a hazard, as, in the figures he has shown, the minimum time given for the embrittling of such steels is about three-quarters of an hour. Does the effect take place in a much shorter time? Three-quarters of an hour is much in excess of the time for a welding cycle, when the junction, parent metal, or the weld metal itself could be at the dangerous temperature. I don't think it would have much effect there. I think the effect would be more serious in other cases. I have in mind fairly heavy castings of austenitic steels where cooling rates, during cooling in the mould, and in subsequent heat-treatment to relieve stress, might be sufficiently prolonged to make them extremely brittle. In that connection I think it is a very valuable piece of work.

Mr. E. P. PEREGRINE.—It is with some diffidence that I put forward what might be extremely critical questions on Mr. Bull's most interesting paper. I have been impressed by the work Mr. Bull and his colleagues have done on heat-resisting steels.

I have not had an opportunity of consulting the paper beforehand and basing my remarks on Mr. Bull's address and on the illustrations shown, it would appear that the 26% chromium/5% nickel steel is not of the columbium or titanium type.

I should like to ask Mr. Bull how far he regards this steel as representative of austenitic steels (as might appear from its position on Fig. 12 also may we take his results as applying solely to steel of that analysis or are we justified in generalising for all steels of similar position on this diagram.

Mr. Bull comments that the heating of duplex steels at temperatures of 650° C. and above indicates a progressive weakness with time. He has shown evidence in the form of Izod test results and certain hardness figures in other cases which do tend to show a deterioration through time, but this evidence of deterioration is shown as occurring at 800° C. This temperature is above that at which these steels are normally used and more positive evidence of deterioration at, say 650° C. for longer periods than those to which the diagram relates, is required. This evidence should preferably be in the form of creep strain/time since this is the sort of evidence which designers wish to have.

Materials of this austenitic type will be widely used in gas turbines and similar engines and I would wish to see the work with which this paper deals extended to allow of the greater application of welding processes to these materials. At present we seem to be very wary about adopting welding for highly stressed parts at high-temperature applications, as for example, in the case of welding turbine blades on to a disc. We even appear to be behind the Americans in this respect.

Professor C. E. PEARSON.—The experimental results on the effect of nitrogen on a chromium steel series are interesting. It is shown that nitrogen has the affect of controlling grain-size in the cast state, and in impeding grain-growth during fabrication or welding, but is ineffective in the sense that steels, once coarsened, can

not be refined by heat-treatment. In addition, however, we get these marked hardening effects and, presumably an increase in brittleness accompanying it. Now referring this information to welding, it is clear that if, using welding rods containing 16/18% chromium, the nitrogen pick-up was to be anything like 0·2% as has been suggested, then the result is going to be dangerous, and it would be essential to apply subsequent heat-treatment to soften the weld metal.

In view of Mr. Bull's remarks on abnormal nitrogen contents in chromium steels after welding, is it his experience that when austenitic chrome-nickel electrodes are used, the amount of nitrogen absorbed is also particularly high and may have adverse effects?

Mr. Bull has hinted that ferritic chromium steels with 16–20% chromium might be more fully used than they are at present. In this connection, is it within his experience that intergranular corrosion of the type known as "weld-decay" occurs in such steels? This seems to be a possibility in view of the variable solubility of carbide in ferrite which they possess.

Finally, what is his firm's attitude, from the point of view of corrosion resistance, to the carbon content of the steels? To what extent do they regard it worth while (and possible) to aim at extremely low carbon contents, and how much progress have they made in this direction?

Author's Reply

The explanation of the hardening effect of nitrogen additions to chromium steels, raised by Mr. Turnbull in his comments, appears to lie in the fact that the low nitrogen end of the iron-nitrogen system is of substantially the same form as the corresponding portion of the iron—iron carbide system. There is a gamma zone similar to that in the iron carbide system with a eutectoid at about 1·5% nitrogen which occurs at a temperature of approximately 600° C., below which there is an alpha zone as in the iron carbide diagram. Although the system is complicated by the effect of pressure, and the relations between the phases at the higher temperatures are still somewhat uncertain, the system seems to have distinct possibilities because of its similiarity to the analagous phase in the iron carbon system and the possibility of the formation and retention of "nitrogen martensite" appears to be well established. Consequently, it is reasonable to suppose that the effect of nitrogen additions to chromium steels will be essentially the same as that of carbon additions. Some confirmation of the truth of this is to be found in the various hardness values given in the tables for the nitrogen-chromium irons. The 16% chromium steel with the nitrogen addition behaves as an ordinary hardenable and temperable steel, and the same effect could have been obtained by a suitable increase in the carbon content, which would certainly have been of a greater amount than the requisite nitrogen. If the chromium content is increased to 21% and 26%, the capacity of the material to harden even with nitrogen additions is reduced. This would also happen in the case of increase in carbon, although the inherent hardness of the nitrogen-containing alloys is slightly higher than the corresponding alloys without nitrogen, which again would occur with an increase in the carbon content. The occurrence of a clear transformation in the 16% chomium-nitrogen steels is analagous to any hardenable material and the occurrence and preservation of nitrogen martensite is quite clearly established in these steels cooled from temperatures above about 950° C. As in the case of carbon, progressive increases in nitrogen do not make the higher chromium steels hardenable and in any case nitrogen cannot be added *ad lib* because of the tendency to cause wildness or blowing.

It is evident that the absorption of nitrogen by high chromium steels of about 16–18% is likely to produce an air hardening material and should this occur in welding then the deposit metal is likely to have an abnormally high hardness, and, unless such welds are tempered, the deposits will have all the disabilities associated with high hardness, and whilst this of itself would not make such material unsuitable for welding, it is a condition which may arise and to which attention should be drawn.

As regards the behaviour of the duplex austenitic steels on reheating, the hardness figures shown were for reheating times of three-quarters of an hour and longer and it is agreed that three-quarters of an hour is in excess of the time for an ordinary welding cycle. When reheated for shorter times these materials show only a negligible increase in hardness for reheating times up to 20 minutes, but there is an appreciable drop in impact even with reheating times as short as five minutes. It should be understood, however, that the loss in impact and increase in hardness is very susceptible to variation in composition, but that, generally speaking, the greater the amount of ferrite in the material in the softened condition the greater will be the hardness developed and the more severe the loss in impact on reheating.

The point about the cooling of fairly heavy castings is of interest, and a relevant experience on this point may be given. A bar of one of these highly duplex steels was, in error, slowly cooled from hot rolling. In the ordinary way the hardness of this material as rolled is about 50 tons, but this slowly cooled bar had a hardness of 75 tons and broke into several pieces when reeled.

The 26% chromium, 5% nickel steels commented upon in the paper and referred to by Mr. Peregrine, did not contain either columbium or titanium. In the author's opinion, steels of this type would hardly come under the normal heading of austenitic steels since they are composed largely of the ferritic phase, but a number of steels which might more properly be termed austenitic do contain appreciable quantities of the ferritic constituent, and experience shows that any steel which in the softened condition is duplex will on reheating, at some temperature for some time, show an increase in hardness to an extent depending on the actual proportions of ferrite and austenite. Experience also shows that these steels embrittle, again to an extent depending on the proportions of austenite and ferrite, but the loss of impact occurs after very much shorter reheating times than are required to develop maximum hardness. Although for most steels there is a temperature at which changes in hardness and impact occur most quickly, longer times at temperatures either slightly above or more generally below the optimum time will produce the same effect. The austenitic steels which have been developed for gas turbine work to date contain a high nickel to chromium ratio, and it has been shown in the paper that this tends to promote a condition resistant to reheating in respect of loss of impact and increase in hardness. Long time reheating tests on these materials, however, do show some increase in hardness and a loss of impact, but the impact value, even after reheating for

times of about 4,000 hours, does not come down to the very low figures which would be obtained on less stable austenitic material.

Mr. Pearson's remarks on the effect of nitrogen on chromium steels are covered in the reply to Mr. Turnbull. As regards austenitic materials, the addition of nitrogen causes an increase in yield point and, to a less extent, in tensile strength, but it does not materially impair the toughness. This behaviour again is analagous to that of increase in carbon and appears to constitute further evidence that the effect of nitrogen is fundamentally similar to that of carbon as an alloy addition.

A phenomenon very similar to weld decay has been observed in 20% chromium-iron sheet, but the precise conditions under which this effect occurs are rather obscure and the phenomenon is certainly not anything like so easily and reliably reproduced in the chromium-iron as in the ordinary austenitic steel.

As regards the effect of carbon content on resistance to corrosion, generally resistance to corrosion deteriorates with increase in carbon, either in hardenable stainless steel, with the high-chromium irons or austenitic steel, but in the former, of course, the carbon content is governed by the mechanical properties required in the material. As regards the 20% chromium irons, it is possible and indeed customary for these materials to be made with low carbons—i.e., of the order of 0·05/0·10%. In the case of the austenitic steels, low carbon materials can be made which are resistant to weld decay probably by virtue of their very low carbon contents. Such materials are, however, difficult and expensive to produce regularly and on the whole it is better to produce a reasonably low carbon and stabilise it with one or other of the well-known additions.

Solution of the Problem of the Kursk Magnetic Anomaly

By Associate Professor V. Rikman

Magnetic iron ores have been known to exist in the Kursk district of the Soviet Union for many years and much work has been devoted to investigations and prospecting without achieving great success. In 1930, however, the study of this magnetic anomaly was resumed on an extensive scale and rich ores containing up to 70% of iron were found capable of being smelted without previous concentration. It is estimated that these rich ores will exceed 340 million tons. About 300 ft. of earth covers the ore bed and it carries accumulations of water-bearing sands, but the problems of exploiting the deposits are likely to be solved and a new iron and steel plant built near Kursk. Brief information of these developments are given.

UNDER the five-year plan at present in operation in the U.S.S.R., one of the tasks in the field of metallurgy is to organise iron-ore mining in the district of the Kursk magnetic anomaly. This means that the corresponding section of the plan will see the initiation of the practical solution of a problem first presented more than 150 years ago.

The magnetic anomaly in Kursk district was first detected by Academician Inokhodtsev in 1784, when, in preparing a map of this district he found a magnetic deflection by more than 5° from normal. In the course of more than a century, investigations of this anomaly were of a sporadic nature and lacked the necessary material means. What was chiefly determined was the zone in which the anomaly spread.

In 1874 a deviation of the magnetic needle was detected near the city of Belgorod (the extreme south of Kursk Province). In 1883–1884 strong magnetic anomalies were discovered in Belgorod district. In 1889 the strongst of all the ascertained anomalies was found in the vicinity of Neikhayevo Village. In 1896 the Russian Geographical Society invited T. Moureau, director of the Paris Magnetic Observatory, to investigate the magnetic anomaly, and he came to the conclusion that it spread over a considerable part of the Kursk Peninsula. On this basis the Russian Geographical Society and the Kursk Province Zemstvo entrusted the further study of the problem to Professor Leist of the Moscow University, who worked on it from 1896–1918—i.e., for more than twenty years. Leist arrived at the conclusion that the reason for the magnetic anomaly was a large concentration of magnetic iron ores in the bowels of the earth, and this conclusion attracted the interest of speculators who provided means for further research. However, Prof. Leist indicated the wrong spots for drilling the two first deep holes, where, at a depth of 212 and 225 metres, no iron ore was discovered. As a result, he was deprived of financial support and subjected to attacks on the part of the disappointed speculators who had bought up the land in the district. He was even assailed by some representatives of the scientific world. Leist, however, continued his explorations at his own expense and in his free time. Unfortunately, the results of his investigations remained unutilised and in 1918 he died abroad.

Next, a special commission, headed by Academician Gubkin, after working on this problem from 1922 till 1926, discovered at a depth of 150–200 metres. a powerful layer of magnetic quartzites, containing nearly 35 per cent. of iron and 35–40 per cent. of silica. The reserves of this quartzite amount to nearly 200,000 million tons. An investigation of the processes of concentrating these quartzites showed the possibility of obtaining from them rich concentrates. The first stage of the solution of the problem of the Kursk magnetic anomaly was thus completed. But with the volume of iron production possible at that time and in view of the far from full utilisation of the iron ore resources of Krivoi Rog,

development of mining of the Kursk quartzites and their concentration was premature, and the further investigation of the Kursk magnetic anomaly was therefore suspended for the time being.

Before long, however, the Kursk magnetic anomaly once more attracted attention. The adoption of the first five-year plan for the development of the economy of the U.S.S.R., which was completed in four years (1929–1932) and the rapid increase in the production of pig-iron and steel, after the completion of the restoration period, made it necessary to enlarge the raw material base of the iron and steel industry in all districts of the U.S.S.R.

A study of the Kursk magnetic anomaly was resumed on an extensive scale in 1930, and this time important new results were obtained within a brief period. Whereas huge resources of iron quartzites were discovered here before, rich ores containing up to 70% of iron were found in this region in 1931. These ores can be smelted without previous concentration, and the prospects of their rapid utilisation are therefore extremely favourable. The ascertained reserves of ores with such a high percentage of iron are sufficient to supply raw material for two or three large metallurgical plants.

It is difficult to over-estimate the economic importance of the discovery of iron ore in the centre of the European part of the U.S.S.R. Up to recent times in the Central and Western European districts of the Soviet Union, production of steel constituted only 18%, and of pig-iron about 8% of the total output, whereas consumption of metal in these districts exceeded 40% of the total consumption in the U.S.S.R. Enormous quantities of metal are transported to these districts from the Ukraine, the Urals and even from Western Siberia.

A new large iron and steel industry will be created in the centre of the European part of the U.S.S.R. to work on the ores of the Kursk magnetic anomaly situated at a distance of only 400 km. from the coking-coal deposits in the Donets Basin.

By 1936 it was already fully established that in the region of the Kursk magnetic anomaly there are no less than 340 million tons of rich iron ores and over 200,000 million tons of poorer iron quartzites. The significance of these figures will become clear when it is borne in mind that even should the pre-war pig-iron output in the U.S.S.R. be trebled the iron reserves in this district would provide sufficient raw material to all Soviet iron and steel requirements for 1,000 years.

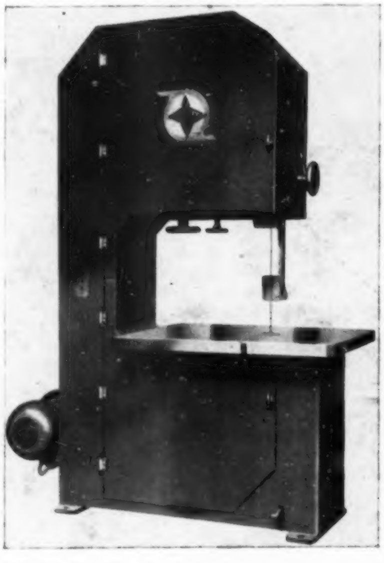
Soviet scientists and technicians have already solved the problem of smelting pig-iron from quartzites similar to those of Kursk. The smelting of such ores in blast furnaces without a preliminary treatment would have been too costly since it demands a very great quantity of coke. The iron quartzites must, therefore, be subjected to a preliminary mechanical treatment—namely, crushing them into small fragments to be passed through magnetic separators so as to separate the particles containing iron from the empty rock, and then baking the particles into lumps on aggomeration bands. By the adoption of this method it will be possible to utilise the colossal reserves of iron quartzites in the district of the Kursk magnetic anomaly for the development of the iron and steel industry on any scale. At the present stage a more restricted task is set: to mine only rich iron ores which do not require concentration before smelting in blast furnaces.

To tap the fabulous resources of the Kursk magnetic anomaly is, however, not such a simple matter. The road to it is barred by huge accumulations of water-bearing sands which lie over the ores. These sands complicate mining exceedingly and create the danger of a breakthrough of the water into the mine workings. Consequently, although the depths of the ore deposits in this district are quite ordinary for modern mining technique, the struggle against the sands will require special, fully reliable pit constructions. A study of the conditions of ore-mining was conducted before the war in an experimental pit.

At present a study is also being made of the bold and radical proposal of Soviet engineers to remove by powerful excavators or hydraulic excavators, the 90-metre layer of earth covering the ore and of deflecting the waters of the sands into a river channel so as to provide the possibility of open mining of iron ore. In this case, after enormous initial expenditure of labour, the subsequent exploitation of the ore deposits will be much easier and less costly. All these problems will have to be solved in the course of the 1946–1950 five-year plan period.

The ore mined will at first be smelted in the existing iron and steel works in the central districts of the European part of the U.S.S.R. and possibly also in Donbas. But in the subsequent five-year period, new large iron and steel works are to be built not far from Kursk. Here one of the most powerful and promising iron and steel districts of the U.S.S.R. will be created.

Sheet Metal Cutting Bandsaw



The "Midsaw Hyspeed" sheet metal cutting bandsaw.

A RECENTLY improved machine for cutting sheet metal is the Midsaw Hyspeed bandsaw designed and manufactured by the Midland Saw and Tool Co. Ltd. The remarkably high running speeds and accurate cutting performance of this machine are remarkable features. The running speed of the bandsaw is 16,000 ft. per minute and its value in the field of high speed sheet metal sawing is demonstrated by the ease with which it saws through steel plate up to ½ in. thick. Metal sheets are cut as quickly as they can be fed to it.

The materials and workmanship are of a high order, and, as can be seen in the accompanying illustration, all working parts are totally enclosed. The design permits a wide variety of work on the large area table (48 × 36 in.) which is accurately machined and carefully mounted to control vibration and to ensure smooth cutting. Internal hydraulic brakes, dual operated from a single foot lever, are fitted to both wheels.

The Engineering and Marine Exhibition

A Symbol of British Vitality and Initiative

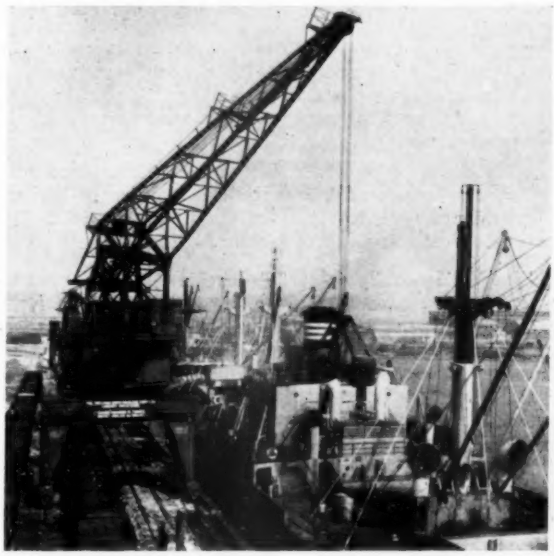
Despite the difficulties encountered as a result of shortages in raw materials, manpower and fuel, the Engineering and Marine Exhibition, which opens on August 28th, will show the resilience and initiative of British industry. The Exhibition embraces the whole of the Main Hall and National Halls at Olympia, together with their galleries—an increase of 45% on the 1937 Exhibition. Former exhibitors are well represented, but many newer trades ancillary to shipping and engineering will add interest to the display. Some of the more salient features are briefly referred to in this pre-review to assist readers who will be visiting the Exhibition and to give those unable to attend a brief summary of some of the exhibits.

THE general arrangement of this Exhibition, which opens at Olympia, London, on August 28th to September 13th, follows the long adopted practise of sectionalisation; but it will be noted that whilst all the old sections are larger than before the war, the newer sections are supported to the limits of the space available. In addition to the main section devoted to shipping and engineering, a section is concerned with the foundry trades, another with welding, and some new sections. Among the latter is that devoted to electricity, embracing a complete range of generation, transformation, distribution and utilisation of power in engineering, on shipboard and in signalling. There will be many demonstrations, but probably the demonstration of more general interest will be that of radar in its modern applications. And it should be remembered that this wonderful invention was evolved from British brains. A fully equipped radar station, with the most modern devices, will be erected on the roof of Olympia. In the following notes are given brief summaries of some of the interesting and typical exhibits, an examination of which will bear out our opinion that British technical, engineering and commercial ability were never higher. Her achievements during the war, including radiolocation, "Fido" fog disperser, "Pluto" pipe lines, "Mulberry" harbours, and her part in the development of the atomic bomb, all bear eloquent testimony to her capacity, and this Exhibition shows that, with increasing supplies of raw materials, British products will again take their place in the forefront of the world's markets.

Shipping and Engineering

Vickers Armstrongs, Ltd., shipbuilding and repairs, engineering, both heavy and light, and aircraft construction, are activities for which the name of Vickers-Armstrongs has become famous throughout the civilised world. From a small beginning more than a century ago, the finest inventive brains and skilled craftsmen have combined in the building of an organisation equipped to supply many of the needs of the modern world, on land, on sea and in the air. (Stand No. 5–6, row R, Grand Floor, National Hall).

In addition to shipbuilding and repairs and aircraft production, the various works of this Company are fully equipped for all types of both heavy and light engineering. Its range is very wide, including the design and construction of cement-making plant; crushing and grinding plant; condensing plant and auxiliaries; winding equipment for mines; propeller-type pumps;



A new level luffing portal jib crane by Wellman Smith Owen Eng. Co., a model of which is exhibited.

soap and ink mills; chocolate refiners; gears and diesel engines; bridge operating machinery; cranes (hydraulic and electric); hoisting cranes; coal hoists; traversers, capstans, etc.; mine skips and cages; castings—iron, steel and non-ferrous; variable speed gears (hydraulic) and variable delivery pressure pumps; presses, both mechanical and hydraulic of the well-known clearing type; cardboard box-making machinery; "pyramid" hardness testing machines; printers' roller-making machinery and castings (steel and non-ferrous); steel office furniture and equipment; and also built the "Wellington" and "Spitfire" aircraft. This Company recently designed and constructed the passenger aircraft "Viking," which Their Majesties the King and Queen used during their tour of South Africa.

A representative selection of the engineering products of the company will be shown at the Exhibition including machinery for the manufacture of soap and ink, a bottle filling and crowning machine, variable speed gears, a model of a vibration damper, hardness testing machine, box-making machinery and industrial accessories. The toilet soap plodder, for example receives milled soap ribbons and extrudes them in the form of a solid, highly

compressed soap bar of a size and shape to suit the finished tablet. The heavy compression results in a high polish being imparted to the soap bar and minimises "cracking." It has an aluminium-silicon worm and is lined with stainless steel to prevent staining of the soap through metallic contamination and a patented safety device is incorporated to protect the machine against overloading.

Hydraulic transmission of power is becoming increasingly recognised as being the modern solution to most power control problems and "VSG" variable speed gears and pumps have established a reputation for reliability and efficiency. The "VSG" exhibits comprise: Typical "VSG" mark III type "K" gear fitted with handwheel control; a small size working model type "C" "VSG" hydraulic variable speed gear; and a working model of a four-ram type electro-hydraulic ships' steering gear as supplied by Messrs. Brown Bros. and Co., Ltd., Edinburgh, operated by a "VSG" variable delivery pump.

The Vickers hardness testing machine was developed as a result of research for a thoroughly reliable and accurate means of testing hardness of metals applicable to all classes of work including those of a high degree of hardness, very thin sheets and finished parts. The load on the diamond indenter is applied, maintained and released automatically, and the result given in Vickers pyramid numerals are internationally recognised in the accurate determination of hardness values.

The Wellman Smith Owen Engineering Corporation, Ltd., Stand 6, Row N, ground floor, National Hall, are showing a 1-ton Wellman mobile tyre cheese-handling machine; a model of a new type of crane, specially made for operating on their stand at this Exhibition; Ross operating valves, including a recently introduced pilot control valve which will be in operation; universal burners of gas and/or oil-firing of industrial furnaces; and the Wellman quick reset shunt limit switch, which has been specially developed for cranes and other types of hoisting machinery.

The principal exhibit is the mobile tyre cheese-handling machine, designed and manufactured for the handling between the furnace and forging press of hot steel blanks and cheeses up to 1-ton in weight and 44 in. in diameter. It is designed on similar principles to those adopted for Wellman mobile furnace chargers and forging manipulators, as will be seen in the illustration in connection with the recent installation of the handling machine in a mechanised forge described elsewhere in this issue.

All motions are operated by hydraulic pressure, power being obtained by means of twin pumps coupled to an electric motor. The power for the electric motor is collected through a flexible coupling connected to a spring-loaded cable drum mounted to a building adjacent to the operational area of the machine. If required, however, the electric power unit can be uncoupled from the pumps and replaced by a diesel engine with no major modification to the Handler, thereby allowing the machine to be entirely independent of external power supply.

The gripping gear can be rotated continuously in either direction. The grips are operated through the medium of a double-acting hydraulic cylinder situated at the rear of the lifting arm and rotation of the grips is obtained through gearing and hydraulic motor mounted on the lifting arm. The gripping motion is provided with a holding recuperator to ensure that no loss of gripping pressure can occur whilst the machine is manoeuvring the blank. The lifting bar is raised and lowered by twin cylinders and cranks situated at the front of the chassis. The range of lift is from floor level to 6 in. above the horizontal—the working height being dependent upon the furnace requirements.

Level Luffing Portal Jib Cranes.—The working model of a new level luffing jib crane, is representative of the first British post-war dockside crane to be supplied to the French Government for re-equipping French ports devastated by war. Three cranes, each of 15 tons capacity, installed at Le Havre, have proved highly satisfactory in service, and repeat orders for a considerable number of others have been received. Cranes of this type have also been supplied to Russia.

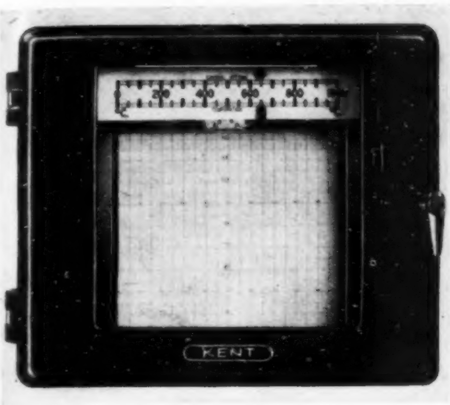
Specially developed in anticipation of the urgent need in shipping centres throughout the world for new lifting machinery, this crane incorporates an entirely new principle of screw-operated level luffing motion resulting in speedier movements, lower running and maintenance costs and simplified control.

In place of the usual complicated rope systems, the Wellman luffing principle allows a direct run of hoisting rope between barrel and load. The jib is also completely self-balancing by virtue of the fact that the upper and lower connecting links are so arranged that the point of their intersection is always vertically below the centre of movement of the jib. When the radius is decreased, the jib tail rope sheaves move downwards through a distance corresponding to the resultant vertical lift of the jib head. This allows for rope being paid out in accordance with the lift, thus ensuring that the load is constantly held on the same horizontal plane. The reverse takes place when the radius is increased. Furthermore, as the horizontal velocity of the load during a change of radius is substantially constant, control cabin movements are greatly simplified with a consequent saving in operational time.

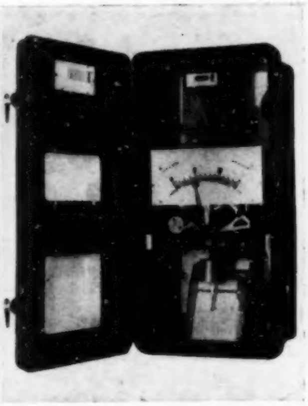
Ross Operating Valves.—Ross operating valves for the control of single and double-acting cylinders are of the poppet type, which means simplicity of design, delicacy of control and speed of operation. Standard valves, which include hand, foot, mechanical and solenoid controlled types, will be exhibited by Wellman Smith Owen Engineering Corporation, Ltd. In addition, however, a special ensemble of the recently introduced Pilot control valve will be in operation. The Ross air controlled master valve used in conjunction with pilot valves makes possible sequence operation, semi-automatic and fully automatic operation, and so-called remote control.

Universal Burners.—The gas and oil burners exhibited have been developed to meet the need for a burner incorporating a high standard of combustion with extreme flexibility. In the design arranged for gas only, any industrial gas can be used, whether clean and cold or hot and dirty, without modification to the design. This burner can be instantly converted to burn oil by removing a sight hob fitting on the inlet gas bend, the oil burner can then be screwed into this gas bend and used without alteration to the supply and control of combustion air. This arrangement of the burner is shown in the accompanying illustration.

George Kent, Ltd., Stand 2a, row E, ground floor, Grand Hall, are exhibiting a complete range of water meters and industrial instruments. The Multelec potentiometric temperature recorder-controller is of special interest to metallurgical engineers and is shown



Kent Multilec potentiometric pyrometer for recording or automatic control of temperatures.



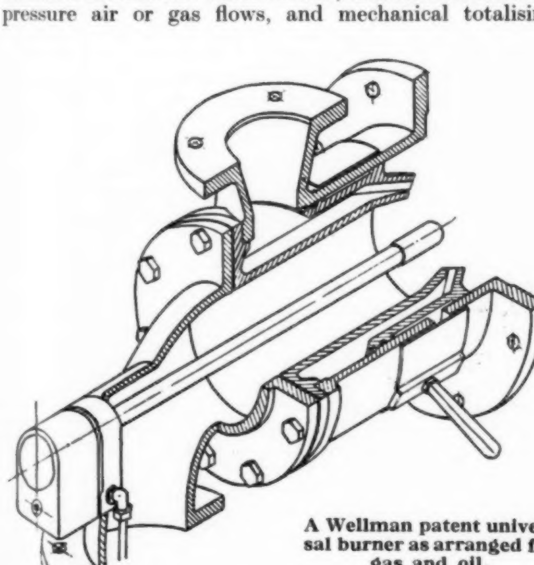
Kent Ring Balance meter for air or gas flow measurement.

Metal spraying pistol by Metallisation, Ltd.

in various forms including an indicating electrical on/off furnace temperature controller and a recording temperature controller fitted with the new Mark 20 air-operating control unit, referred to elsewhere in this issue. The versatility of this instrument is demonstrated by its application to pH measurement, shown as a working exhibit, and its wide use for the measurement of CO_2 and conductivity.

Attention is also drawn to the new ring balance meter for the measurement and recording of low-pressure air or gas flows, such as blast-furnace gas, coke-oven gas, etc. This instrument is shown mounted on a panel and fitted with the new Mark 20 air-operating control unit.

A number of steam meters are shown including the KM recording and integrating type with 12-in. diameter disc chart and continuous mechanical integrator, and the shunt type known as the RS/C for direct totalising of steam flows in small pipes. The RS/C meter is also used for water and compressed air measurement and is shown in all three forms with appropriate dials. In addition mechanical water meters, manometers for low-pressure air or gas flows, and mechanical totalising meters for oil and petrol are shown in a variety of models and sizes.



A Wellman patent universal burner as arranged for gas and oil.

Babcock & Wilcox, Ltd. will be occupying the same position as on former occasions—i.e., Stand 3, row G, ground floor, Grand Hall. The exhibits will consist mainly of models and a series of drawings and photographs. The models will include pulverised fuel fired high head boilers, the Babcock-Detroit stoker-fired boiler, integral furnace boiler, single pass Babcock marine boiler and oil-fired divided furnace controlled superheat marine boiler, and Stirling boilers. Everything for the boiler house and for the stokehold will be shown, including electric cranes of all types. Typical examples of oil burners are also shown.

E. Green & Son, Ltd. Engineers interested in problems of fuel economy and steam plant efficiency will find the display of this Company on Stand No. 4, row D, ground floor, Grand Hall of special interest. Originally invented in 1845 by Edward Green, the Economiser is still the simplest method of recovering waste heat and raising the efficiency of steam boilers. The main features of the standard vertical tube Economiser—i.e., long life, low maintenance, automatic cleaning, large water capacity and dependability, are such that under certain conditions this type has still no superior.

Modern electric power stations and large industrial plants have in recent years adopted much higher working pressures and the horizontal gilled tube Economiser constitutes a reliable and efficient construction in this field. In this connection Messrs. E. Green & Son, Ltd. have introduced the " Premier Diamond " horizontal Economiser. It is available in two types, one having cast iron tubes with integral cast iron gills, for pressures up to 650 lb./sq. in.; the other type has steel tubes with cast iron gills shrunk on, suitable for any pressure up to 4,000 lb./sq. in.

Clyde Blowers, Ltd., soot blowers for land, marine and locomotive boilers, for cleaning their heating surfaces, are shown on Stand b, Section 1, gallery, National Hall. These blowers are designed to give automatic movement by the turn of a wheel, including steam admission and shut off. *Power operation.* Operation and control is obtained by electric or hydraulic systems applied to the soot blower as self-contained power units which give remote control. This design of electrical operation is already fitted on board ships

complete with automatic sequence control, enabling the boilers to be kept clean. A push-button starts up the system from the engine room and the blowers systematically operate one after the other until the cycle is completed. ***Automatic drain valve.*** This valve and strainer is used on all "Clyde" installations, as it opens and closes automatically.

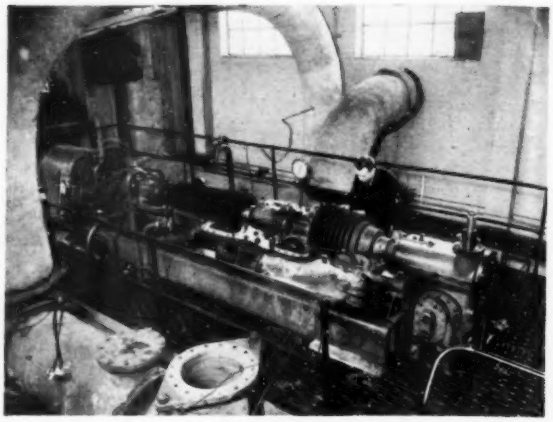
C. A. Parsons & Co., Ltd. exhibit a one-sixteenth scale model of one of two 50,000 kw. 3,000 r.p.m. turbo-alternators complete with surface condensing plant constructed for the Bunnerong power station, Sydney, Australia. The turbine operates with steam at a pressure of 600 lb./sq. in. at the stop valve, a temperature of 825° F. and exhausts at a vacuum of 28·5 in. Hg. It is of the three-cylinder type coupled to a single alternator and exciter. The alternator is of the three-phase type generating current at 11,000 volts, 50 cycles, and is ventilated on the closed circuit system which includes the main brush gear and exciter. This Company also exhibits a bladed model of a sector of a low-pressure turbine shaft designed for a tip speed of 1,200 ft. per second. The blades are of the integral type in which the combined blades and spacing piece are produced by rolling from a single billet. To reduce the centrifugal stress in the blades in the last row they have been rolled hollow, and to prevent erosion, hardened shields are fitted to each blade in the last two rows. Samples of blades in each row will be available for inspection.

Among other interesting exhibits by this Company is the first commercial axial flow blower constructed at Heston Works in 1901 and supplied to Messrs. Cookson and Sons, Howden-on-Tyne. It was designed to deliver 3,000 cu. ft. of air per minute at a pressure of 1·75 lb./sq. in. This machine is the prototype of the modern axial flow blower which has made possible the development of the gas-turbine plant.

Albright & Wilson, Ltd. This display, on Stand d, Section 12, gallery, Grand Hall, will be divided into two sections, one of which will deal with applications of organic silicon compounds, and the other with the phosphates which are used in treatment of water.

In the first section silicone compounds made by the Dow Corning Corporation will be displayed. As distributors of these products, Albright & Wilson have much information about their uses which will be of interest to engineers. There will be demonstrations of the behaviour of silicone insulation in electric motors running at high temperature and also of silastic rubber gaskets under load at about 200° C.

The first commercial axial flow blower constructed at the Heaton works of C. A. Parsons & Co., Ltd. in 1901.



500 B.H.P. Parsons gas turbine plant.

To those interested in the manufacture of intricate metal parts made from hard or difficult alloys, the "lost wax" precision casting technique offers a possible solution to an awkward problem. The part played by ethyl silicate as a refractory mould binder will be shown.

W. H. Dorman & Co., Ltd., on Stand 3, Row A, ground floor, Grand Hall, will be showing, amongst their other exhibits, a lightweight, high-speed diesel engine, type 8 VRM. This is an eight-cylinder engine suitable for marine work, having the eight cylinders in vee formation in blocks of four, the power output being 100 B.H.P. at 2,200 r.p.m. This unit has been extensively used for fast vessels of various types requiring single-screw, twin-screw or triple-screw installations.

Sir George Godfrey & Partners, Ltd. Typical of many of auxiliary equipment for diesel engines is the Marshall Industrial Roots' blower on Stand g, section 14, gallery, Grand Hall. This blower is the outcome of experience which was gained by Sir George Godfrey & Partners, Ltd., during the last war, when they were employed in the development and manufacture of cabin blowers for high altitude fighter aircraft. Blowers for this application had to deliver air which was completely oil-free and machines capable of such delivery are in great demand for many industrial purposes. The Marshall blower is used by diesel engine manufacturers both in England and abroad for the supercharging of traction and stationary engines, and the 500 buses ordered from Messrs. Crossley Motors by the Netherlands State Railways for their long distance services have this blower as standard equipment. The larger industrial blower, an example of which will be on exhibition, has been specially designed for use in heavy industry for such applications as gas boosting and cupola blowing, or wherever low-pressure air is required.

Davey, Paxman & Co., Ltd., on Stand 13, Row J, ground floor, Grand Hall, are showing, among their many exhibits, a full-scale sectional model of their V-type 12.RPH diesel engine. Engines aggregating

2,000,000 h.p. were supplied by this firm during the war and form the background to the design of this particular engine. These engines are built up from a number of self-contained assemblies, which, by their light and compact form, assure ease and speed in routine maintenance operations.

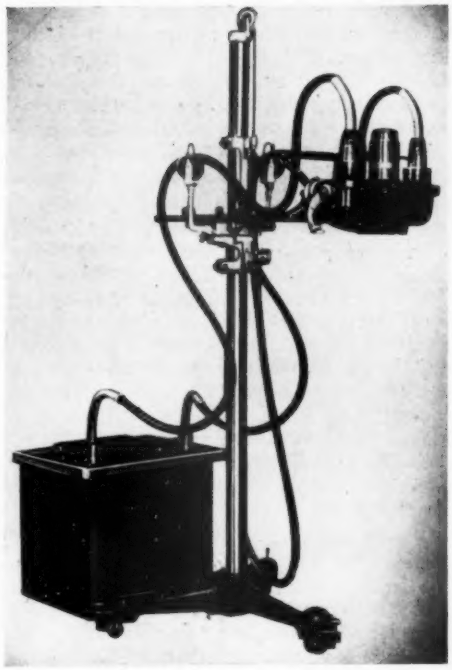
Thos. Firth & John Brown, Ltd., on Stand 8, row H, ground floor, Grand Hall, feature a wide range of cutting tools including twist drills, reamers, milling cutters, files, and " Mitia " carbide-tipped tools. The theme of the exhibits will be from the steel to the finished tool. Two lathes will be in operation showing the use of tungsten carbide tools and high-speed steel. The " Millenicut " milled files will also be demonstrated. An interesting exhibit will be a range of packed tools showing the care taken to preserve the tools by the adoption of modern packaging methods.

In collaboration with Messrs. Firth Brown Tools, Ltd., Messrs. G. & W. Lowe, Ltd., will be showing their new electric plane which has not only new features of interest to the user but undoubtedly, in workmanship and design, it surpasses its American rivals. This plane, together with the very neat precision surface grinder, will be demonstrated and technicians will readily appraise the advances in technique which this Company have to offer.

The Glacier Metal Co., Ltd., on Stand f, Section 14, gallery, Grand Hall, are showing a range of 200 of their standard wrapped bushes made from steel strip, lined with a lead-bronze alloy by means of a sintering process. The range is from $\frac{3}{8}$ in. to $2\frac{1}{4}$ in. bore, and each bush is supplied drilled and grooved, ready for assembly. In addition to bushes, plain half bearings are shown, together with a range of tin and lead base alloys covering all applications in which white metals are employed. Bronze bars, comprising phosphor-bronze 2B8, lead bronze LB10 and lead bronze LB20, suitable for engineering applications in which bronze bushes are employed, will also be available.

Victor X-ray Corporation, Ltd., Stand H, Section 16, gallery, Grand Hall, will feature two typical equipments from their standard range of shockproof industrial X-ray apparatus—the Model OX-250 unit and the Model OX-140 Mobile/Stationary unit. The former is rated for continuous operation at 250,000 volts and is capable of efficient radiography of steel-sections up to $3\frac{1}{2}$ in. It has, of course, a very wide field of useful application in the non-destructive testing and inspection of castings, forgings, welded structures and other heavy-density fabrications. The OX-140 unit is a lower-powered equipment with a continuous-operation rating of 140,000 volts, and a penetration-range from 30–140 kV. It is designed primarily for the radiographic inspection of light alloys, plastic and laminated fabrications, etc.

English Steel Corporation, Ltd., Stand A, Section 3, gallery, National Hall, together with their subsidiaries, The Darlington Forge, Ltd., and Taylor Bros. & Co., Ltd., are showing a range of heavy forgings, ships' forgings and castings, drop forging for marine engines, alloy steels, precision ground and engineers' small tools. The exhibits of small tools will include several new and patented tools, such as " Vickers " adjustable machine reamer with micrometer adjustment of blades, the E.S.C. expanding hand reamer with micrometer adjustment of blades, the inserted blade-milling cutter with an improved method of locking blades, and an adjustable floating reamer.



X-ray unit by Victor X-ray Corporation, Ltd.

Macrome, Ltd., Stand C, Section 7, gallery, Grand Hall, are giving details of their special steel treatment applied to cutting tools. The process gives to the tools added active resistance to wear, fatigue and breakage. The treatment (which is varied according to the steel composition) permeates the whole bulk of the steel. It does not " harden " the tool, and Rockwell or Brinell readings are unaffected. As the treatment affects the whole molecular content, the benefits are maintained throughout the normal useful life of the tool, however much it is ground down or worn. The treatment is applied to tools and steel parts after the usual hardening, tempering and grinding processes have been carried out. In other words, when the tools or parts are normally regarded as ready for use.

Metal Sprayers, Ltd., Stand K, Section 14, gallery, Grand Hall, show a steel skeleton of a building metal sprayed as a protection against corrosion, together with photographic illustrations of a wide variety of work done by this process. Also on view will be a die built up with high carbon steel into a wood mould ; and electric-cooker parts, domestic coal economisers and porcelain insulators, a hatch combing, metal propeller, exhaust manifolds, etc., all sprayed with zinc or aluminium as a protection. In addition, particular attention is directed to the value of the process in building up worn mechanical parts, such as crankshafts, wheel hubs, pump shafts, etc.

Metallisation, Ltd., Stand 15, Row K, ground floor, Grand Hall, will demonstrate the spraying of pure metals and alloys on mild steel, plastics, cloth, paper, etc., by means of the wire method. The object of the metal-spraying process is to obtain a deposit of metal

on a surface in order to protect the original surface against corrosive conditions, or in order to build up to a given dimension. This object is achieved by melting a wire of the desired protective metal in a blowpipe flame and spraying the metal as it becomes molten by means of a gaseous propellant. This is done by means of a small tool, termed a pistol, which weighs about 3½ lb. The pistol as well as its application will be demonstrated.

Acheson Colloids, Ltd., Stand c, Section 4, gallery, Grand Hall, show the industrial uses for "dag" fine dispersions of graphite, illustrated with examples from light and heavy engineering, metal working, electrical trades and certain specialised branches of engineering. The whole is intended to present a panorama of the applications of colloidal graphite and semi-colloidal graphite, and to provide practical data. It is noteworthy that "dag" dispersions are now available in mineral oil, water, acetone, white spirit, alcohol and other carriers. The method of forming dry films and coatings will be graphically illustrated, and the research and practical properties of such coatings explained.

The Rawlplug Co., Ltd., Stand 5, Row K, ground floor, Grand Hall, will have a general display of Rawlplug fixing devices and will demonstrate practical applications. Amongst an extensive range on view is the new Rawlplug "H" toggle. This device is a metal member suspended on a bolt, which when inserted through a hole in a wall drops on the reverse side by the pull of gravity. As the nut is tightened on the bolt the member is drawn against the back of the wall to form a brace. This device can be of special value when the reverse sides of walls are inaccessible. Also on show will be rawlanchors, gravity toggles and spring toggles which have been developed for making firm fixings to wallboards, laminated boards, hollow bricks and tiles, sheet metal and asbestos, etc., where it is difficult to use orthodox fixings. The display units show several examples of excellent uses for these fixing devices.

Amongst the range of Rawlplug tools on view are chrome molybdenum alloy chisels which have a high shock-resisting quality. When repair or erector gangs are equipped with these chisels they have the advantage of resharpening on the spot by means of a second cut file.

Tangyes, Ltd., Stand 5, Row L, ground floor, National Hall, are exhibiting a good range of their products. Typical examples include two vertical diesel engines of 20 and 60 B.H.P. capacity, a horizontal diesel engine of 42 B.H.P. capacity, two "AR" type centrifugal pumps, 1½ in. and 6 in. sizes, one horizontal duplex boiler feeder, a vertical single ram pump, a 16-ton hydraulic sleeving press, and a range of hydraulic-lifting jacks, hand-pressure pumps, and factory-heating stoves.

Considerable interest is attached to a new design 25-ton universal testing machine which will permit all types of tensile, compression, beam, shear and bending tests. The load-measuring device is entirely separate from the hydraulic straining system and is capable of measuring the applied load with very great accuracy. It is of the metal diaphragm type, hydraulic pressure being generated behind the diaphragm without internal friction, resulting in an accurate load indication. The whole unit is hermetically sealed and once fitted the machine requires no attention. Self-aligning mountings for the tensile and compression testing members ensure that at all times specimens are truly loaded.

Manganese Bronze & Brass Co., Ltd., Stand 6, row E, ground floor, Grand Hall, have works at Birkenhead and Ipswich; from the former will be exhibited their patented "Scimitar" propellers, which are claimed to have effected improvements of over 10% in actual service performance. From Ipswich works there will be two main classes of exhibits, one showing the range of extruded, rolled and forged high-duty bronzes and brasses, while the other shows various applications for Oilite self-lubricating bearings.

This firm originated the use of manganese bronze for the manufacture of marine propellers and are specialists in high-tensile bronze and brass alloys, manufacturing a range of proprietory high-strength alloys, such as Immadium bronzes, Crotorite aluminium bronzes, Parsons' manganese bronze, etc., which are well known in industry.

The British Thomson-Houston Co., Ltd., Stand 5, row N, ground floor, National Hall, have designed their exhibits to show the important position held by this Company in electric ship propulsion and marine auxiliary electrical services, including lighting equipment for ships, shipbuilding, dockyards and general engineering industries. The achievements of the Company in electric propulsion and auxiliary services, including applications of the "constant current system," are recalled by various photographic reproductions of celebrated ships, but at the present time chief interest is perhaps centred on the development of the gas turbine, diesel-A.C. electric propulsion, electromagnetic couplings, and the use of alternating current for ships' auxiliary services.

An outstanding exhibit is the actual "Whittle" gas turbine jet engine, manufactured by this Company, which in a Gloster aeroplane made the first successful flight in the world, May 15th, 1947. Another feature is a model of the gas turbine-alternator set which is under construction for the Anglo-Saxon Petroleum Co., Ltd. It is to be installed eventually in the "Auris," a tanker of 12,600 tons gross which has diesel-electric propelling machinery. There are four diesel-alternators, one of which will be replaced by the gas-turbine alternator so that actual performance can be exhaustively tried out at sea.

Interest is also attached to reduction gears for the varying conditions of torque and speed in marine service, which can be supplied for single, two, and four diesel engine arrangements, with reduction ratio to suit the desired propeller speed. The wheels and pinions are of the double helical type, and are mounted in a fabricated steel casing which also houses a Mitchell thrust bearing on the output shaft. Silent running of gears, combined with high efficiency and long life, is of special importance in marine work and depends upon accuracy of tooth formation. The teeth of these gears are cut by hobbing machines specially designed by the Company, and are tested for accuracy of shape with a precision instrument capable of detecting very small errors in pitch and profile.

The Mond Nickel Co., Ltd., Stand 2, Row G, ground floor, Grand Hall, will show the extensive advisory and research services of their Development and Research Department available to engineers. These services are provided by means of reports and correspondence, personal visits and practical advice rendered on the spot, covering every stage from the choice of

material by the designer, through the various production and fabrication processes to investigation of service requirements and conditions. Those who have metallurgical problems should take the opportunity of discussing them with members of the technical staff of this Company, especially as improvements in technique and materials developed to meet war needs are now available for post-war industrial development.

Henry Wiggin & Co., Ltd. will exhibit a range of their high-grade nickel alloys on the same stand as The Mond Nickel Co., Ltd. Among the more important are the Nimonic series of alloys. These high-temperature materials, best known for their contribution to the development of the gas turbine in this country, will be seen in the representation of a turbo jet, which includes part of a turbine rotor, with the turbine blades in position, and flame tubes. The turbine blades are made in Nimonic 80, and the parts subjected to the highest temperatures in the flame tubes are fabricated from Nimonic 75.

Special interest will be taken in the wide range of corrosion-resisting materials on view, including Monel, pure nickel and Inconel whose applications in corrosive conditions are illustrated in various media, while the high-quality electrical resistance materials displayed, together with high-quality pure nickel strip, produced to meet special requirements in the radio industry, are noteworthy exhibits.

T. H. & J. Daniels, Ltd., Stand 10, Row B, ground floor, Grand Hall, are showing the latest improvements in presses for moulding plastics. The experience of the past few years is reflected in the neatness of a 50/75 ton press used for moulding the Bakelite and Beetle type of plastics and this can produce a variety of articles ranging from electrical plugs, switches, etc., to vacuum-cleaner components. Ingenious methods of platen heating are embodied in the press and the time required for producing the finished article has been considerably reduced. The technique of production of plastic powder pellets as an alternative to using loose plastic powders is catered for by a pre-forming machine and in certain cases examples of pre-heating by high frequency will be demonstrated to show how time in moulding is very considerably reduced.

A. C. Wickman, Ltd., Stand 5, row P, ground floor, National Hall, have concentrated on practical demonstrations and in the Electronics Division are showing many interesting examples of the wide application of some of their plastic welding, dielectric heating and induction heating machines. Of special interest to plastic fabric users is their demonstration of welding seams of plastic garments. Another exhibit worthy of attention is the dielectric heater which greatly accelerates operations requiring rapid heating or drying. The great advantage of this form of heating is that the rise in temperature is caused by molecular disturbance in the article under treatment and is therefore uniform. The range of exhibits includes the induction heater, which performs heat-treatment operations in a fraction of the time required by conventional methods. A typical example is the hardening of automobile engine valve ends, demonstrated on a 5 K.W. set. A 1 K.W. model demonstrates its application to tool-tipping operations, " Wimet " tungsten carbide tips being brazed to turn tool shanks with great speed and simplicity.

A display of " Spedia " and " Neven " diamond wheels is also included, and " Ardite " hard-facing rods which will be demonstrated. Possible applications of these hard-facing rods cover all branches of the engineering industry, from the blast furnace, where bleeder valves, mud guns and shears may be treated, and the mining industry, where coal cutter picks and crusher teeth need hardening, to the motor, aircraft and machining industries where exhaust valves, tappets, aircraft tail skids, cams, etc., benefit from a wear-resistant surface inexpensively and simply applied.

Rediffusion, Ltd., Stand g, Section 6, gallery, National Hall, exhibit two main fields of their activities, radio communications and industrial radio heating. Principal emphasis is on the marine communications equipment, but the section illustrating three main applications of radio heating to industry will also be of great interest to visitors. The range of Redifon radio heating equipment is too large for inclusion in the Exhibition, so that specimens illustrating three applications of the technique are shown giving demonstrations of induction heating, dielectric heating and plastic welding. The smallest equipment in the range for each of these applications is utilised.

Induction Heating.—This process will be demonstrated by an equipment powered with a 350 watts Redifon R.H.22 generator. The task is the hardening of small steel parts on a mass-production basis, the rate being 1,500–1,800 pieces per hour with complete and automatic quality control using unskilled labour.

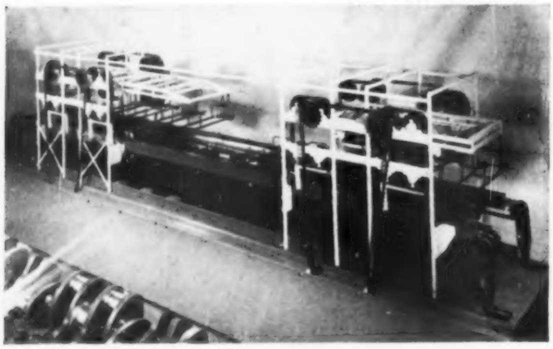
Dielectric Heating will be demonstrated on a 350 watts R.H.23 radio heater, a type which is widely used throughout the plastic moulding and other industries. The pre-heating of moulding powder, glue-lin setting and other applications of this process will be illustrated.

Plastic Welding.—The welding of thermoplastic materials by radio heating is a new technique which will be demonstrated on the Redifon Model J.P.1 radio-heat plastic welder, an equipment which is simple to use, economical to operate and consistent in results. The most common application for this process is the welding of P.V.C. and similar materials though success is being achieved on new materials every day.

Electric Furnace Co., Ltd., Stand 4, row Q, ground floor, National Hall, show sample parts treated in the Efco-Tocco high-frequency equipment for high-speed heating for surface or through hardening, annealing, brazing, soldering and forging. An Efco electronic heater will be in operation brazing carbide tool tips to mild steel shanks.

For hardening high-speed steel and for tool tipping it is usually necessary to use controlled atmosphere to prevent scaling ; with the Efco-Sentry furnace, however, a carbon muffle surrounds the work, this slowly burns away to produce an atmosphere which prevents carburisation or decarburisation. Thus, this type of furnace, which will be exhibited, needs no atmosphere generators to start, adjust, maintain or clean. The elements are of the non-metallic type and the furnace may be used for heat-treating carbon steel, high-speed steel, tool tipping and preheating.

Another interesting exhibit is the Efco Ajax-Hultgren electrode type salt bath, with a maximum temperature of 1,350° C., a midget type of which will be shown. A



Working model of a continuous plating plant by Electric Furnace Co., Ltd., showing simple transfer mechanism.

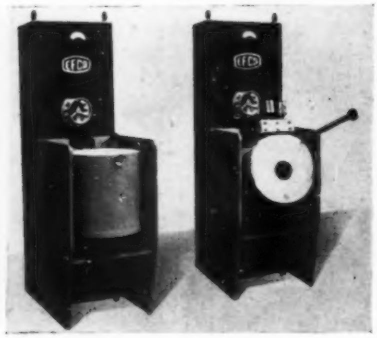
variety of heat-treatment work can be done in this plant—carburising, tempering, nitriding, high-speed steel, hardening and neutral heat-treatment. It has the advantage of being a compact unit ready to plug into the mains unit, and because of the variety of heat-treatment work with which it can cope it is eminently suitable for the small works or tool room where expense of the larger and more expensive salt baths is not justified.

The working model of a continuous plating plant, shown on this stand, will attract much attention. It incorporates a new type of transfer mechanism suitable for electroplating, pickling and similar plants. This transfer mechanism is of an extremely simple design consisting essentially of a frame carried on four chains passing round four sprockets. All four chains are driven from the same motor, and are so arranged that the frame can be made to travel on a rectangular path. Hooks are fixed to the lifting frame so that they engage with work bars or crates lifting them forward one stage with each operation of the transfer mechanism.

A considerable advantage of this type of mechanism is its flexibility, as a series of Auto Units can be mounted above the process tanks and can be moved quite readily to allow for extensions to the plant or the introduction of new processes. Furthermore, additional units can be installed so that other processes can be operated in the same line.

Wild-Barfield Electric Furnaces, Ltd., Stand 1, row A, ground floor, Grand Hall, show a range of laboratory furnaces, both tubular and rectangular. The former are available in single or twin-tube models with tube sizes either 12 in. × 2 in. or 20 in. × 2 in. In every case, with standard equipments, temperature regulation is by means of a built-in hand-operated energy regulator type temperature controller, and requisite pilot lights are fitted. The rectangular muffles have chamber sizes ranging from 8 in. × 3 in. × 3 in. to 19 in. × $7\frac{1}{2}$ in. × 5 in. Smaller models are completely self-contained and have built-in temperature controllers and pilot lights.

The recently introduced " Workshop " furnace, rated at 8kW. will be demonstrated. This horizontal batch-type furnace has a chamber length of 18 in. with a door opening of 9 in. × 5 in. and has been designed specifically for workshop use. The equipment is self-contained and incorporates a hand-operated energy regulator type



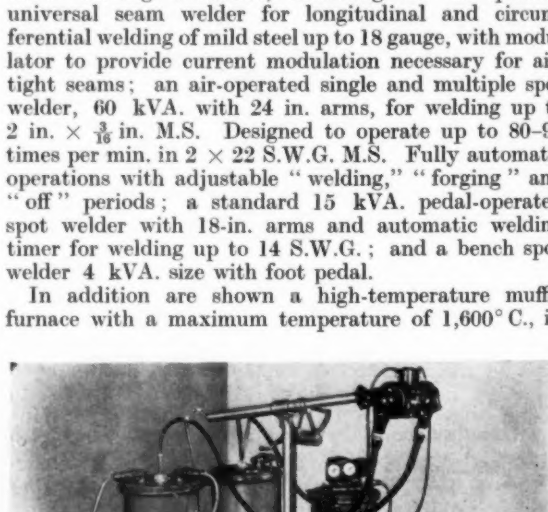
Efco-Ajax-Hultgren electrode type salt bath (midget type).

temperature control panel, pyrometer, fusible pattern excess temperature cut-out and door switch. A flue with damper is fitted and the door is spring-loaded to facilitate operation. The furnace, for which the maximum recommended operating temperature is 1,050° C., will be demonstrated using, for the first time, a new atmosphere.

Other equipments exhibited will include the " Hairpin-Minor " furnace designed for moderate production outputs, the Toolroom Tempering furnace embodying forced air circulation, and the " E.S.B. Minor " electrode salt bath for the heat-treatment of small components, particular those of high-speed steel. Induction hardening will be demonstrated on a Ferranti-Wild-Barfield machine, which is referred to elsewhere in this issue. In addition, various metallurgical analytical equipments will be shown, including the Vickers Pyramid Hardness Testing Machine, the Spekker Steeloscope and the Spekker Photoelectric Absorptiometer.

Siemens-Schuckert (Great Britain), Ltd., Stand 15, ground floor, Grand Hall, are showing a wide range of their welding machines, including an air-operated universal seam welder for longitudinal and circumferential welding of mild steel up to 18 gauge, with modulator to provide current modulation necessary for air-tight seams; an air-operated single and multiple spot welder, 60 kVA. with 24 in. arms, for welding up to 2 in. × $\frac{3}{16}$ in. M.S. Designed to operate up to 80–90 times per min. in 2 × 22 S.W.G. M.S. Fully automatic operations with adjustable " welding," " forging " and " off " periods; a standard 15 kVA. pedal-operated spot welder with 18-in. arms and automatic welding timer for welding up to 14 S.W.G.; and a bench spot welder 4 kVA. size with foot pedal.

In addition are shown a high-temperature muffle furnace with a maximum temperature of 1,600° C., in



Marine type industrial X-ray apparatus by Siemens-Schuckert.

which the heating element is protected by hydrogen or cracked ammononia ; a double-muffle furnace in which the lower muffle is used to pre-heat to about 1,000° C. and the upper for rapidly raising the temperature to 1,300° C. as for treating high-speed steel ; a scale model of the mechanical part of a 10-ton arc furnace with run-out and rotating shell ; and industrial X-ray equipment. This latter is the "Marine" type industrial X-ray apparatus rated at 150 kV. 9 mA. for the radiological inspection of welded seams on board ship or in engineering shops. Penetrative power of up to $1\frac{1}{4}$ in. in iron or steel, using X-ray films with intensifying screens. Designed specially for shipyard use—the dimensions of the individual components being such that they can be manhandled into awkward positions thus enabling X-ray inspection of otherwise inaccessible welded sections to be undertaken.

Stewarts & Lloyds, Ltd., Stand 4, row F, ground floor, Grand Hall, will have on view a wide range of steel tubes for all purposes, including tubes for the conveyance of steam, gas, water, oil and sewage, and a variety of joints and couplings to suit various working conditions. Other exhibits include examples of protective linings and coverings for tubes, and moulding boxes ; a selection of coils, and several types of brass and gunmetal valves and fittings. Examples of fabricated ship and shipyard equipment will also be on show, including derricks, davits, masts and tubular steel sheer legs.

Imperial Chemical Industries, Ltd. exhibit the products of its Alkali Division on Stand 14, row D, ground floor, Grand Hall, and feature the activities of its Metals Division on Stand G, section 3, gallery, Grand Hall. At the former, particular interest will be centred on an entirely new process for the descaling of metals, and developments in the use of sodium carbonate for metal refining and of caustic soda for de-enamelling steel.

Sodium carbonate has long been used, in several branches of iron and steel manufacture, for refining metal. It has now been proved that the use of a basic-lined ladle enables 80% of the sulphur in cast iron to be removed, or 30% more than is possible with a siliceous-lined ladle. Demonstrations have also shown that phosphorus can be removed from low silicon cast iron by treatment in a basic-lined ladle with a mixture of sodium carbonate and mill scale.

The sodium hydride process provides a new technique for descaling metals. When sodium hydride—a powerful reducing agent—is present to the extent of about 2% in a bath of molten caustic soda, held at a temperature of 350°–370° C., oxide scale is reduced to a soft metal powder which is easily removed, and there is no attack on the underlying metal. No corrosive fumes are given off, nor do the chemicals employed attack mild steel, used for the construction of the plant—a model of which will be exhibited.

The Metals Division's stand shows the many applications of cupro-nickel, "Alumbro" and the other well-known alloys associated with I.C.I. Tubes and plates in the new copper-nickel-iron alloy for seawater trunking will be displayed, as well as plate, sheet, strip, rod, tube extrusions and brass and copper wire, together with aluminium alloy products for a multitude of engineering and marine purposes.

The **Hoyt Metal Co. of Gt. Britain, Ltd.,** Stand h, section 14, gallery, Grand Hall, will be showing their standard anti-friction alloys for all types of bearings ; a wide range of bearings, precision finished, steel or bronze-backed, lined white metal, and also the copper-lead type ; bronze in various forms, such as bars, castings, solid drawn rods and tubes ; die metal, a zinc-base alloy for forming dies, plastic moulding, etc. ; forming tools ; fluxes, tinning compound, etc. ; fusible alloys, matrix and tube bending metals, etc. ; and various gauges and qualities of solder.

K. & L. Steelfounders & Engineers, Ltd., Stand 4, row C, ground floor, Grand Hall, are showing a selection of steel castings covering a wide variety of industries, chief of which will be railway locomotive and wagon castings, excavator, crane and steam roller castings and also castings for the electrical industry. "Coborn" Cast Steel Anvils ranging from 28 lb. to $4\frac{1}{2}$ cwt. will also be displayed.

Two special features will be the Jones' "Super 40"—a 3-ton mobile crane fitted with a 40-ft. lattice jib, and the new Jones' "Super 15" mobile crane. This new 15-cwt. crane travels under its own power and steers wherever it is wanted, carrying full load. Hoisting, slewing and travelling motions are power driven, all with variable speed control. Both hoisting and derricking have automatic brakes and power-lowering gear is fitted. The power unit is a 6 h.p. "Coborn" industrial petrol engine, with air cooling which avoids the risk of damage by frost.

Tungum Sales Co., Ltd., Stand 10, row G, ground floor, Grand Hall, will have a comprehensive exhibit showing tungum alloy in the form of tube, bar, rod, sheet, strip and wire, together with samples of gauzes, wire ropes, springs and castings. The outstanding features of this alloy are its high strength-to-weight ratio, resistance to corrosion, high resistance to torsional and vibrational fatigue, high thermal conductivity and ability to withstand high pressures. It is noteworthy that a separate section is being devoted to the tube manipulation service offered by the Company and aircraft pipes, pre-formed plumbing units and components for general engineering purposes will be on view.

The Aluminium Development Association, Stand c and d, section 5, gallery, National Hall, will have a display of castings, forgings, stampings, and examples of various types of welding. A number of new marine applications for aluminium alloys will be on view. Supporting the various exhibits in the wrought or cast conditions, are technical bulletins together with a wide range of other technical literature and flow sheets. Specimens of work done in connection with the application of light alloys to the superstructures of ships. Technical experts will be available to discuss problems associated with the application of aluminium alloys to engineering.

Almin, Ltd., Stand b, section 4, gallery, National Hall, embraces the display of the activities of the component companies in the group represented by the Almin Group including, International Alloys, Ltd., Renfrew Foundries, Ltd., Southern Forge, Ltd., Warwick Production Co., Ltd., and Structural and Mechanical Development Engineers, Ltd. The latter Company specialise in prefabricated structures in aluminium alloy and "Alcrete" buildings (aluminium alloy and foam-concrete). Renfrew Foundries, Ltd. specialise in sand and die castings in aluminium alloy and a wide range of large sand castings will be shown, including 2,

A housing casting in aluminium alloy A.C. 7 for 6-cylinder diesel engine by Renfrew Foundries, Ltd.

3 and 6 cylinder diesel engine blocks and crank cases, castings weighing from 100–300 lb.; a diesel engine impeller 40 in. diameter; a 12 ft. tenoner beam casting; a 5 ft. scavenge pipe casting; a 1,200 lb. machine tool bedplate casting; and a 650 lb. machine tool main frame castings. In addition, a selection of smaller sand and die castings will also be shown. Another member of the Group, Southern Forge, Ltd., will show a wide graduated range of aluminium alloy extrusions; a selection of stampings and pressings; and a prefabricated structure consisting of extruded aluminium alloy.

Birlec, Ltd., Stand 9, row A, ground floor, Grand Hall, will demonstrate high-frequency induction heating. The demonstration unit shows how localised heating—for hardening or other purposes—can be applied to small parts rapidly, uniformly and with complete regularity by means of a mechanised feeding arrangement giving a high production of strictly uniform quality without requiring highly skilled operation.

The latest type of Birlec rocking indirect arc electric melting furnace will be shown. This equipment is built in capacities from 10 lb. to 1,000 lb. or larger, afford exceptionally rapid melting and close metallurgical control in both brass foundry and iron foundry work, being particularly suitable for making complex alloys of either ferrous or non-ferrous types. The furnace exhibited is of 500 lb. charging capacity.

Heat-treatment equipment is represented by a Birlec standard general purpose furnace, widely used for annealing, carburising, hardening, tempering and other heat-treatment operations in toolrooms or small-scale production shops. Completely automatic temperature control is provided, and a feature of the design is the provision of a heating element on the inner face of the door which neutralises front losses and ensures completely uniform heating throughout the furnace chamber. This furnace will be shown in operation.

The large production furnaces built by this Company, both for melting and heat-treatment, including high-frequency induction heating apparatus of various kinds, will be represented by illuminated photographs and technical literature. In addition, a small working model of the Birlec-Tama low-frequency induction melting furnace for aluminium and light alloys will be exhibited.

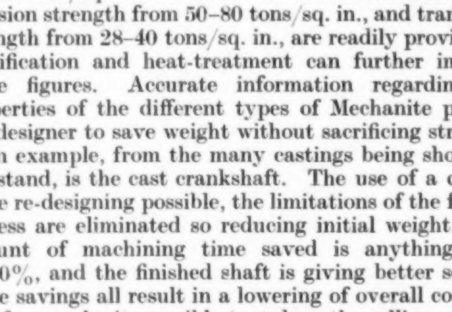
The Non-ferrous Die Casting Co., Ltd., Stand 1, row F, ground floor, Grand Hall, will exhibit gravity and sand castings in a large range of non-ferrous alloys, which will show progress in the development of the die-casting process. Some of the brass die-castings shown will be in the 20–30 lb. range. Castings in aluminium alloys, produced by a new process which is claimed to eliminate porosity, will be shown, as well as castings in naval brass, high-tensile brass, aluminium bronze, and N.F.P.Z., giving a tensile strength of 45 tons/sq. in., and aluminium alloys to such specifications as L8, L33, D.T.D. 424, D.T.D. 428, and LAC 112A.

The Sheepbridge Stokes Centrifugal Castings Co., Ltd., Stand 9, row B, ground floor, Grand Hall, will direct particular attention to their cylinder liners and will exhibit "Centrard" nitrogen hardened liners, "Centricast" liners, with the bores chromium hardened by their associate Company British Van der Horst, Ltd., and in their standard material "Loded Centricast." Many wet liners of different designs will be shown, having bores up to 12 in. diameter.

Machined components and unmachined castings made by the centrifugal process or in sand moulds shown will include a range of cast irons for resistance to heat, corrosion, or abrasion; alloy steels; and a range of alloys of nickel, silicon and molybdenum.

The International Mechanite Metal Co., Ltd., Stand 17, row G, ground floor, Grand Hall. The display of this Company will be designed to show designers and engineers the known and guaranteed physical properties of Mechanite Metal and to demonstrate its wide range of uses. By strict metallurgical control inherent in the Mechanite process, castings in suitable grades can be produced possessing high strength and to figures which can be relied upon as a basis of design. Tensile strength of 16–24 tons/sq. in. in the "as cast" condition, compression strength from 50–80 tons/sq. in., and transverse strength from 28–40 tons/sq. in., are readily provided to specification and heat-treatment can further improve these figures. Accurate information regarding the properties of the different types of Mechanite permits the designer to save weight without sacrificing strength.

An example, from the many castings being shown on the stand, is the cast crankshaft. The use of a casting made re-designing possible, the limitations of the forging process are eliminated so reducing initial weight. The amount of machining time saved is anything from 50–90%, and the finished shaft is giving better service. These savings all result in a lowering of overall cost and therefore make it possible to reduce the selling price of



A range of wet liners by Sheepbridge Stokes Centrifugal Castings, Ltd.

the processed goods sold to the general public. Also shown are some of the control methods used to ensure the production of the exact properties required.

There are 22 different types of Mechanite, each designed to meet specific problems of service in industry and on the stand are samples, photographs, transparencies where the actual castings would be too big, showing the application of these types of Mechanite in industry.

Fry's Metal Foundries, Ltd., Stand a, section 4, gallery, National Hall, show, in addition to the standard grades of solder, many special alloys and fluxes for soldering. Special attention is devoted to sweat soldering as a means for economising in labour and materials. In sweat soldering, the solder is located in the assembly as a separate operation, before heat is applied to complete the joint. Products which enable this to be done include the well-known Fryolux solder paint, containing flux and powdered solder, pre-formed rings of solid and fluxed solder wire and washers of solder. Demonstrations are given of the use of these materials using electrical resistance heating for sweating the joints.

Foundry Trades

General Refractories, Ltd., Stand 12, row F, ground floor, Grand Hall, exhibit refractories requirements of all types of industrial furnaces. Basic refractories exhibited will include a comprehensive range of magnesite, chrome-magnesite and dolomite bricks for open-hearth, electric and reheating furnaces, cement kilns, etc. Of special interest are the dolomite "341" bricks, manufactured entirely from British dolomite. These bricks played an important part during the war, and in this period their development was advanced sufficiently to enable them to be used in place of previously imported materials in comparison with which they have given equal, and in many cases, superior performance in use and their development and manufacture is being continued on a large scale.

Firebricks exhibited include the well-known "Glenboig," "Davison" and "Foster" ranges for boilers, locomotives, cement kilns, blast furnaces, hot blast stoves and industrial furnaces generally. Specially featured is an electric furnace roof in Sillimanite material and an exhibit of "Amberlite" heat-insulating products in which the low thermal conductivity of these materials is demonstrated with special reference to their function in reducing heat losses in furnace structures with resultant fuel economies. Samples of moulding and silica sands to meet every requirement are on view, together with many examples of fire cements, jointing materials and monolithic ramming compositions.

Stewarts & Lloyds, Ltd., Stand 16, row E, ground floor, Grand Hall, will be displaying a comprehensive selection of foundry and basic pig irons, gannister, limestone, billets, blooms, rounds, steel castings and hot and cold rolled steel strip, as well as examples of their steel and tube-works' by-products.

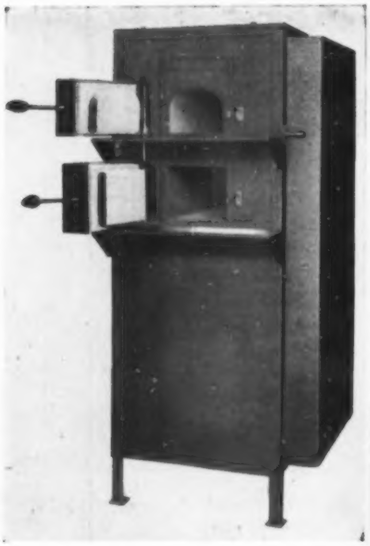
The Morgan Crucible Co., Ltd., Stand 13, row C, ground floor, Grand Hall, are showing crucibles, basins and other Morgan plumbago products for the foundry. Salamander and salamander super crucibles for melting aluminium and other non-ferrous metals, malleable iron, and alloy cast iron and steel will be featured in a wide variety of shapes. Every modern type of crucible furnace will be represented from the lift-out for jobbing foundries, the Bale-out for aluminium die-casting and for brasses and bronzes, to the hand-tilted crucible furnace for general foundry work, and finally—the effortless hydraulic tilting crucible furnace which can be operated from a separate remote control. A new type of crucible furnace designed for the melting of swarf and metal powders will also be on show. This furnace has its body and special bottle-shaped crucible in continuous rotation whilst melting and so prevents the formation of fused masses of metal which are difficult and wasteful to handle and which would have to be broken up by vigorous poking.

The Morgan hydraulic oil-fired tilting furnace, 600 lb. capacity.

A section will be devoted to Morganite carbon moulds and cores and welding rods, while the high-grade refractory ware to be exhibited will include firebrick, refractory tubes, furnace shapes and fused alumina, sillimanite and silicon carbide refractories. Pure oxide refractories for research development, and production are worthy of special mention. For instance, "Triangle" ware in pure alumina, magnesia and beryllia is employed in the ceramic, metallurgical and allied industries. It is invaluable alike for research, development and production.

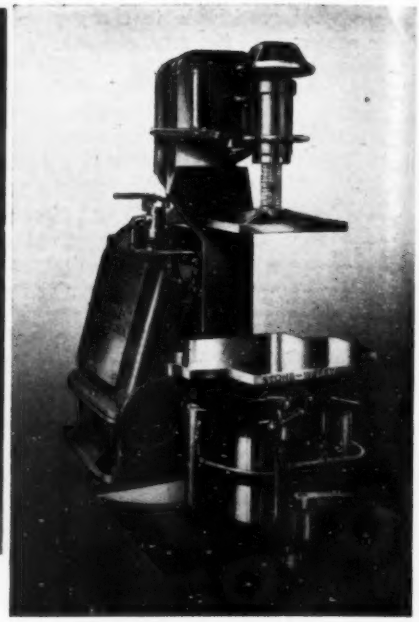
Certain metallurgical processes, such as those for instance in the radio industries, demand particularly high temperatures. These are achieved with the aid of the highly refractory pure alumina. Grooved furnace tube formers in this material carry the molybdenum or tungsten resistor wire providing the heat. Pure magnesia ware is particularly useful for high purity basic type melting. Pure beryllia is exceptionally valuable as a high-temperature refractory for contact with carbon, or in carbonaceous atmosphere, or in very high vacuo. "Triangle" pure oxide crucibles are universally employed for high frequency in the metallurgical industry and in high purity glass melting.

British Insulated Callenders' Cables, Ltd. Stand 7, row O, ground floor, National Hall, are showing a standard model of their squeeze strip 324 magnetic moulding machine. It is the smallest machine of this type they manufacture and will accommodate moulding boxes 17 × 13 in. × 3½ to 5 in. deep. The power unit is also of standard type but the stripping frame and combined machine table and pattern plate supporting



A double muffle furnace by Siemens-Schuckert.

Morganite carbon core for nickel-chromium casting.



A straight draw moulding machine by Stone-Wallwork, Ltd.

stool are built to suit the requirements of individual customers. All operations are controlled by push button.

A pattern plate vibrator is attached to the machine table and arranged to operate from a single-phase A.C. supply while a pattern plate heater is fitted inside the machine table. This heater unit can be altered to work either on D.C. supply, and act as a maintaining load for the mercury arc rectifier, or alternatively, from the single-phase A.C. supply.

Carborundum Co. Ltd., Stand 18, row E, ground floor, Grand Hall, specialise in grinding wheels and all abrasive and refractory materials. The exhibits will comprise crucibles, basins, stands, etc., while refractories for high temperature work, covering both ferrous and non-ferrous furnaces, will be exhibited by a variety of "Carbofrax" and "Alfrax" standard and special shape bricks, tiles, muffles and tubes, included also will be various refractory cements.

Electromagnets Ltd., Stand 16, Row J. ground floor, Grand Hall, as showing a selection of "Boxmag" standard and special permanent and electro-magnetic equipments, many of which will be in operation demonstrating efficiency and representing new types and improvements based on the wide experience gained during the war period. Most of these equipments are covered by various patents and there is a very wide variety meeting practically every industrial requirement, covering lifting magnets, magnetic separators, clutches, chucks, brakes, hold-down gear and the like applied generally for protection, reclamation, purification and transportation purposes or where used for transmission of power, holding-down work during machining and other operations and where welding processes are carried out.

The majority of these products are supplied to steel works, rolling mills, foundries, chemical and refining manufacturers, collieries, coke-oven and washery plants, textile trades, refuse handling plants, glass, rubber, tea, patent foods, plastics, paper, ceramics, oils, cattle food, cork, tobacco, grain and where such similar materials have to be handled.

Many newly developed equipments are too large to show in the space available, but visitors interested will be invited to this Company's works for tests or alternatively arrangements will be made for them to see plants operating under normal working conditions. A development by an associated firm, Blending Machine Co. Ltd., covering blending machines of the continuous and batch type, high frequency sifters for handling powders, semi-solids, lump stuffs and liquids such as glaze, enamel and potters' slip will also be exhibited and most will be operating under working conditions.

J. W. Jackman & Co. Ltd., Stand 17, row D, ground floor, Grand Hall, show a wide range of foundry plant and equipment. Among the exhibits are a sand mill and mixer of patented design; a motor-driven gyratory sand sifter arranged to discharge tailings during sifting; several moulding machines, including a small hand-operated press with swinging pressure head, an Osborn pneumatic jolt squeeze stripper, an Osborn pneumatic roll over jolter, and a pneumatic jolt lift machine; the blowing of cores by compressed air is a relatively recent development and the Osborn pneumatic core blower will attract much attention. In addition will be shown several sand and shot blast machines including a small suction type sand blast cabinet, a medium shot blast cabinet and a shot blast barrel. A further exhibit of considerable interest is a standard Brinell hardness testing machine, arranged for tests at various loads up to 3,000 kilograms and for standard balls 10, 5 and 2·5 mm.

Stone Wallwork Ltd., Stand 21, row H, ground floor, Grand Hall, show many types of equipment

required in connection with the mechanisation of foundries including four models of their range of moulding machines. These machines incorporate the Stone-Wallwork patented shockless jolt squeeze mechanism and are fitted with their " Aerox " air filters ensuring a supply of air to the machines free from moisture and grit. There will be a pair of straight draw moulding machines, a turnover moulding machine, and a snap flask moulding machine. In addition, two electric vibratory riddles will be exhibited.

Although primarily concerned with the foundry equipment section of this Company's products, further exhibits display products of the gear section, which include H. R. and Wallwork reduction gears ; and P.I.V. variable speed gear.

Workington Iron & Steel Co. Ltd., Stand 17, ground floor, Grand Hall, will display samples of hematite irons, Cumberland coke and limestone as used in the Workington blast furnaces. Also on display will be samples of hematite iron, " UCO " refined cylinder irons, and " UCO " refined malleable iron all in machine cast form. A cube of " UCO " cylinder iron which has been highly polished indicates the soundness of this iron for castings.

An interesting feature of the display will be the widely varied selection of castings, in the manufacture of which Workington hematite and " UCO " refined irons have been used. This selection shows the wide range of adaptability and flexibility of the Workington products, for the exhibits range from stator frame castings to boot protectors and reeling rolls to ingot moulds. The company wish to express their appreciation of the valued assistance and co-operation so generously accorded them by their many customers and friends in loaning exhibits for display.

The Constructional Engineering Co. Ltd., Stands 11 and 17, row F, ground floor, Grand Hall, are devoting one stand entirely to demonstrations of such plant as their airless shot blasting machine, core blowing machine, vibratory knock-out, " Titan " core sand mixer, etc. The second stand, with their associates The Adaptable Moulding Machine Co. Ltd., and E. Tallis & Sons Ltd., will include such plant as a bottom section of a " Titan " cupola, a Pari-blast cupola, incorporating individual air control to each tuyère in conjunction with "Metronic" instruments ; a " Titan " cupolette ; a range of gas, oil or solid fuel fired core ovens ; geared ladles and a special type of drum ladle ; and a selection of pattern plates and models for die-cutting machines made with " Titanite " stone mixture.

A very interesting exhibit will be the example of a range of centrifugal casting machines, as this firm recently concluded negotiations for the exclusive manufacturing rights of the Centrifugal Casting Machine Co. of America and hope to be in production in a few months. This exhibit will attract considerable attention.

Further exhibits include pressed steel moulding boxes ; " Adaptable " moulding machines ; portable sand riddle ; snap flasks ; pattern duplicator, etc.

Messrs. Armstrong Whitworth & Co. (Pneumatic Tools) Ltd., Stand 11, row P, ground floor, National Hall, will be showing their full range of pneumatic tools. Of particular interest to the engineering and shipbuilding industries will be the A.W. chippers, riveters, holders-on and grinders, whilst the range of rotary and reciprocating drills and the special models catering for close quarter work will be demonstrated.

Pneumatic tools for the foundry trades will also be largely featured in the form of sand rammers, chipping and scaling hammers, grinders and the necessary hose and air line fittings for this work. For the locomotive and boiler shop this Company's range is of particular interest, especially in the case of the A.W. Reciprocating Drill for tube expanding. For road (concrete) breakers, sump pumps, demolition picks, and pneumatic clay diggers will also be featured.

Not only do Armstrong Whitworth specialise in this extensive range of tools, but they are also the central marketing office for the whole range of stationary and portable air and gas compressors made by their associates Messrs. Air Pumps Ltd., who make a complete range of compressors for air and other gases, in capacities from 2 to 500 cubic feet per minute, for high and low pressures. Several types of compressors will be both exhibited and demonstrated.

Also featured will be products of their associated companies, Sir W. G. Armstrong Whitworth & Co., (Ironfounders) Ltd., and Jarrow Metal Industries Ltd., who will exhibit their world-famous " Closeloy " rolls for the iron and steel industries, marine and other castings in steel, and a range of exhibits covering the well-known New Process Refined Iron.

Foundry Services Ltd., Stand 17, row A, ground floor, Grand Hall, provide a service for producing better castings at lower cost, which embraces ferrous, non-ferrous and light metal castings. This Company assists in supplying foundries with the results of research in forms which permit their ready application in practice. These are in the form of fluxes and preparations which can be seen and examined ; their particular uses will be explained.

In the melting of gunmetals and bronzes, for instance, one of the most important developments is the oxidation-reduction technique for ensuring maximum density and minimum gas content. " Foseco Cuprex " blocks are a simple and effective means of obtaining the required oxidising flux and degassing treatment automatically and simultaneously. Reduction or deoxidation is carried out as a final operation before pouring by plunging D.S. deoxidising tubes. The technique as applied to phosphor and high zinc bronzes is slightly modified.

Hydrogen is a constant source of trouble when melting and casting aluminium alloys, unless suitable precautions are taken. Foseco Coverals provide a cleansing and protective flux cover whilst Degaser Tablets offer an efficient means of sweeping out dissolved gas without the risk and complicated equipment involved in the flushing treatment with chlorine or nitrogen gas. For the aluminium-silicon alloys of the 2L.33 type which need modification treatment, sodium cubes are provided. An alternative means of modification is by way of fluxes containing sodium chloride and fluoride. These are available as special modifying Coverals.

Magnesium based alloys, or even those of aluminium containing 10% or so of magnesium, cannot be melted and cast satisfactorily without the aid of special fluxes to prevent burning, and to give the necessary cleaning and refining treatment. The Foseco range of M.F. fluxes for magnesium and its alloys cater for sand casting and crucible melting, ingotting and the melting of scrap and swarf, and gravity die-casting from bale-out furnaces

while as a dusting medium to prevent oxidation and burning during pouring, there is "Inertex" dusting powder.

A recently developed Foseco product is a magnesium degaser. Solubility of hydrogen in magnesium and resulting porosity is a matter on which opinions differ. Although magnesium degaser will remove hydrogen from solution this is not its chief function. Its major purpose is to effect grain refinement by carbon nucleation within the relatively low temperature range of 740/780° C. The necessity for super-heating to between 850° and 900° C. is thus obviated except for castings carrying heavy sections of 2 inches and upwards. Additionally, the natural scavenging influence of the gases evolved from Magnesium degaser gives rise to some cleansing action in that suspended non-metallics, such as magnesium oxide, are brought to the surface.

A whole range of heat-producing alloy ladle additions applicable to the production of high duty and special cast irons is included. Also means for applying inoculation treatment and chill reduction. Where additions are more conveniently added to the cupola charges there are ferro-alloy briquettes (Cupolloy) and Brix Blocks for reducing oxidation losses, refining the structure of the cast iron and curtailing sulphur pick-up.

The Welding Section

Philips Industrial (Philips Lamps Ltd), Stand 10, row F, ground floor, Grand Hall, will exhibit a range of welding equipment (arc and resistance), magnetic filters and industrial rectifiers. For arc welding are shown two welding transformers and a dual purpose welding plant. One of the welding transformers is a heavy duty, fully portable welding plant for general construction, heavy duty production line welding and maintenance work. The other is a reliable A.C. welding plant for general duty, light to medium fabrications, sheet metal welding and maintenance work. It is fully portable, of compact design, and gives high efficiency with low operating cost.

The dual purpose plant is a general purpose welding unit for light, medium and heavy production work in addition to repair, maintenance and specialised applications. Suitable for light gauge mild steel, alloys and non-ferrous metals. Its portability enables it to be moved to the job.

For resistance welding will be exhibited one of the latest of Philips spot welding equipment. A number of patented features are included in this machine such as the accurate control of welding heat, giving a short welding time, and the electrode pressure control which ensures a quick forging action. In addition, there will be a spot and stitch welder with automatic timing control for light, medium and heavy fabrications, water cooled; a general purpose spot welder, water cooled, pedal operated, for mild steel component assembly; a general purpose spot welder, 15 kVA, pedal operated; a portable welding gun for mass production of light gauge assemblies; as well as welding time control units, resistance welding tools and accessories, etc.

Philips Industrial X-ray Department will display a full range of X-ray equipment specially designed for the industrial user on stand J, section 2, gallery, National Hall. The Macro 100, a general purpose unit, particularly suitable for the examination of mass-produced articles by the visual inspection method. Magnesium castings, plastics, aircraft components are just a few of the many applications of this unit. Of special interest to shipbuilders, marine and constructional engineers are the Macro 150, Macro 200 and Macro 300 units with which it is possible to examine steel from 2 in. to $4\frac{1}{8}$ in. All these units mentioned above are transportable, the underlying feature of a new development in X-ray Inspection technique by Philips. Many power stations have welded high pressure pipe lines and insurance specifications state that the seams in these pipe lines *must* be examined to ensure that they are free from defects. X-ray examination in situ seemed to offer the only solution. A solution to a difficult problem which the industrial X-ray Department of Philips have overcome by devising a mobile van to accommodate a complete dark room together with the necessary X-ray inspection equipment.

Murex Welding Processes Ltd., Stand 11, row E, ground floor, Grand Hall, will exhibit a very wide range of electric arc welding plant, accessories and electrodes. It will include a mobile 400 amp. diesel engine driven set, as supplied in large numbers for work now being extensively carried out in the oilfields, which embodies many unique and special features not usually found in British welding plant. In addition to a 250 amp. self-contained welding transformer, the exhibit will include a 300 amp. motor generator set complete on a trolley and fitted with the Murex remote control regulator. This latest Murex development provides an automatic means of adjusting the welding current of motor generator sets without the need for the operator to leave his work.

Of particular interest is a dual purpose screen and helmet. A special feature of the screen is its patented glass holder in which a plain protective cover glass and a coloured glass are fitted. The plain glass is permanently in position providing an efficient chipping screen. The coloured glass can be brought in and out of position in a split second at the touch of a lever by the thumb of the hand holding the screen. Thus the operator can sight his work up to the last moment prior to the arc being struck. The helmet enables the welder to have both hands free. Fitted with a patented glass holder somewhat similar to that used in the screen described, but operated by an outside knurled knob.

Demonstrations will be given in the welding of ferrous and non-ferrous metals and will include the recently developed Type P.V. electrode, designed for welding deep groove type butt welds in thick mild steel. This special electrode is suitable for the welding of pressure vessels to Lloyd's Class I and is also suitable for welding vacuum equipment and on work which is subsequently vitreous enamelled.

Commercial aluminium bronze electrodes, hard facing electrodes, and a range of electrodes for aluminium and its alloys, are included in many large and small gauge electrodes on view.

The British Oxygen Co. Ltd., Stand 9, row F, ground floor, Grand Hall, will exhibit several interesting examples of equipment developed during recent years. These will be additional to a wide range of this well-known oxy-acetylene welding and cutting equipment for use in the fabrication, repair and maintenance of metal products. The new exhibits will include new types of extra heavy cutters capable of cutting steel ranging from 18 to 84 inches in thickness; one of the latest types of "Shorter" process flame hardening

machine; "Argonarc" welding equipment, and a "Unionmelt" automatic submerged arc welding machine as used in the construction of welded ships, pressure vessels, steel railway wagons, etc.

Experienced staff will be in attendance to discuss practical and technical problems and to give demonstrations of oxy-acetylene processes relating to:—Welding of ferrous and non-ferrous metals; aluminium brazing; oxygen machine cutting; flame gouging for the removal of weld defects, tack welds, etc.; flame cleaning of steel structures for the removal of corrosion and in preparation for painting; Argonarc welding—the modern method of welding magnesium alloys, stainless steel, Monel and Inconel, without the use of flux.

Air-operated universal seam welder.

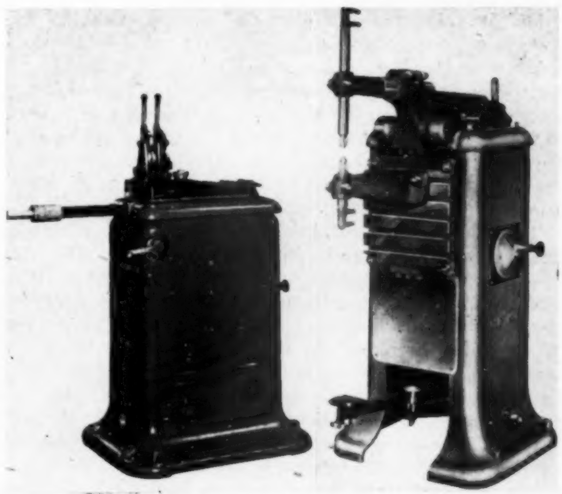
Air-operated single and multiple spot welder by Siemens-Schuckert.

Johnson, Matthey & Co. Ltd., Stand 14, row E, ground floor, Grand Hall, are showing a comprehensive range of silver brazing alloys and Mallory materials for resistance welding. With regard to the former, the great variety of applications of low temperature brazing throughout the engineering industries calls for a wide range of brazing materials, and for the careful selection of the most suitable alloy for a particular jointing problem. JMC silver brazing alloys have been developed over the past twenty-five years to meet these steadily increasing requirements. A comprehensive range of these brazing alloys is available having widely different silver contents with melting points ranging from 630° to 830° C. By comparison with the older brazing alloys, melting at 850° to 900° C., these alloys are in general characterised by greater fluidity, strength and ductility and yield stronger joints with an economy in time both in making the joint and in subsequent cleaning and finishing.

The Mallory range of high strength, high conductivity materials for use as dies and electrodes, has been developed during many years' experience in resistance welding, each material being suitable for a particular duty or range of applications. Mallory designs of standard electrodes, holders and other fittings have also been based upon long and careful study of resistance welding technique.

Hancock & Co. (Engineers) Ltd., Stand 11, row J, ground floor, Grand Hall, are staging practical demonstrations by each of their oxygen cutting machines. In addition to their well-known machines, there will be several special purpose machines developed during the last few years. Of considerable interest will be demonstrations of a new machine for parting off tubes to length, and also a machine for profiling tubes to shape from a template. Interest will also be centred in a portable machine which clamps on a tube, and cuts a hole to a developed shape, either with a vertical cut or a bevel. The main purpose of this machine is to cut a hole in a pipe prior to welding in a branch and it will cut a hole up to 10 in. diameter in a pipe up to 12 in. bore very cleanly and accurately in under three minutes.

Associated with the above Company is Weldcraft Ltd. who are exhibiting a range of equipment for gas welding and cutting which will include the well-known "Aceta" low pressure acetylene generator as well as the "Sight Feed" medium pressure generator now being manufactured in this country under licence. Their "Bronzecraft" rods for low temperature welding by oxy-acetylene will also be shown together with their "Hardcraft" hard surfacing rods. Also exhibited is an automatic gasfluxer for bronze welding or brazing which dispenses with the use of a powdered flux. The fuel gas used is passed through a small fluxing apparatus where it picks up gaseous flux. The flux is fed to the work through flame and by putting just the right amount of flux where it is wanted, speedier, stronger and better joints are made without any residual flux or slag which is always a problem to remove.



An automatic butt wire welder by Holden & Hunt, Ltd. **Universal spot welder.**

Buck & Hickman Ltd., Stand 11, row D, ground floor, Grand Hall, will show arc welding equipment, oxy and acetylene equipment, resistance welding equipment and accessories. The arc welding equipment includes A.C. transformer and AC/DC motor generator

welders, electrode and ground cables, electrode holders, ground clamps, face and head shields, various types of protective clothing, cable connectors and electrodes of all types. The oxy and acetylene equipment includes "Autocet" automatic high pressure acetylene generators, purifiers, purifying material, granulated carbide, various sized welding blowpipes, oxygen and acetylene regulators, gauges, economisers, cutting blowpipes, all types of welding rods and fluxes, goggles and cylinder trollies, etc. While the resistance welding equipment includes spot, butt and seam welding machines from 2kVA to 50 kVA capacity.

Holden & Hunt Ltd., are exhibiting on Stand 16, row H, ground floor, Grand Hall, a complete range of universal spot welders of the manually operated type, in ratings from 5 to 40 kVA. Particular attention is directed to Nos. 1, 2 and 3 automatic butt wire welders, the latter two models having recently been re-designed, and are shown in the new form for the first time at this Exhibition. The motor driven stitch welder is displayed with four-speed motor drive and an electric rivet heater is also on view. Unfortunately, there is not enough space on the stand to exhibit examples of this Company's range of automatic compressed air operated spot welders, but it is likely that facilities to inspect these machines at the works could be arranged for those specially interested.

It will be appreciated that not all exhibitors had full information available at the time of going to press, and it has only been possible to give brief particulars of some exhibits. In every case however, specialists will be available on each stand to supplement this information.

Correspondence

Sponsored Research

The Editor, METALLURGIA.

Dear Sir,

The article in your July issue describing the future activities of the Fulmer Research Institute is most interesting, but one of the main implications is not quite true. In the summary of the article it is stated: "The idea of sponsored research is not new, but the principle has not previously been applied in this country." In point of fact, the principle has been applied by the Midland Laboratory Guild in Birmingham since 1919.

In the third paragraph of the Report covering the speech by Sir Stafford Cripps (p. 120) a question is asked concerning the direction in which small firms could seek assistance in regard to research. It is a fact that for many years firms in the Midlands have been able to turn to the Midland Laboratory Guild for advice and assistance in their research problems. The writer was able to make this point at a recent Conference held in Birmingham by the Federation of British Industries.

The Midland Laboratory Guild helps to bridge the gap specifically referred to by Sir Stafford Cripps. The idea of a co-operative laboratory was first conceived in 1916, and by 1919 the organisation was in existence, serving the technical needs of its Guild members. These firms, all of them important in the Birmingham non-ferrous metal industry, contribute to maintain a fully equipped metallurgical laboratory appropriate to their collective requirements. This co-operative effort makes it possible for the "smaller but enterprising firm" to have research carried out, since the otherwise exorbitant costs of maintaining a laboratory are shared by a number of quite separate contributing companies. These companies are, to some extent, competitors in the non-ferrous trade, yet co-operators in the upkeep of the laboratory, and therein lies the unique aspect of this particular organisation.

Another connection concerns the very large clientele of "small but enterprising firms" comprising the Guild's outside clients—i.e., non-members. These, in addition to the Guild members furnish the Laboratory with a very varied assortment of research and investigatory problems, and the reports resulting from this work are guarded by all the appropriate secrecy as in the case of the Guild members themselves.

Thus for the past twenty-eight years, an organisation has existed in Birmingham to help the small firm by providing research facilities as well as a solution of everyday problems. This "common user laboratory" helps to bridge the gap which undoubtedly exists between the large research organisations and the small firm.

It is felt that the foregoing will be of interest to your many readers, especially in view of the prominence being given by the Federation of British Industries to the technical needs of the small firms.

Yours faithfully,
For Midland Laboratory Guild (1928), Ltd.
(Signed) H. H. SYMONDS,
Scientist-in-Charge.

King Alfred's Place,
Broad Street,
Birmingham, 1.
July 22nd, 1947.

[Although we were aware that many research laboratories carried out co-operative research on behalf of their members, as distinct from the co-operative research organisations representing particular sections of industry and supported by Government grants as well as members subscriptions, we believed them to differ in principle from the recently opened Fulmer Research Institute.

As a result of further correspondence we understand that the Midland Laboratory Guild is supported in the first instance by eleven *quite separate* companies, each operating independently of the other. The work for each firm is carried out with appropriate secrecy. Such an arrangement is, of course, quite different from that which concerns the central laboratory—whether for control or research—which may serve the technical requirements of a group of Companies.

In addition to the above, we understand that the Guild undertakes research and investigatory work for *any* firm at an agreed fee, and the results of this work are the sole property of the sponsoring firm. And, like the Fulmer Institute, the Guild is a non-profit-making concern.

We are glad to pass this information on to readers who are not familiar with the activities of the Midland Laboratory Guild or with the principles under which it functions. As some indication of its success it is of interest to note that during the half-year ended June 30th, 1947, the financial returns, from the research undertaken by the Guild for firms in the Midlands, have reached a record figure in the twenty-eight years of its existence.—EDITOR.]

Recent Developments in Materials, Tools and Equipment

The Mark 20 Air Operated Controller

A NEW controller, known as the Mark 20 controller, is the latest product of George Kent Ltd., of Luton. Although new in design it is based on the latest accepted principles of automatic control, and on long experience in measurement and control in industry. Its special design features include :

1. Differential movement between meter-pointer and setting pointer, integral with controller, dispensing with exact lining up of external link work.
2. Interchangeability of control units without the need of special adjustments.
3. Only one set of bellows are used, and this is well protected.
4. Simplicity and the minimum of mechanism.
5. Minute operating force required, imposing the minimum of restraint on meter movement.
6. Exceptionally long range of sensitivity adjustment.
7. Non-bleed type of air relay.

The control relies on accurate measurement and is, therefore, applicable to the automatic regulation of such values as are measured by the standard Kent measuring instruments such as flow, temperature, pressure, liquid-level, specific gravity, pH, conductivity and other measurable quantities. Thus, it can be supplied with the ring balance meter for low pressure air and gas flows and for low static pressures ; with the Multelec for temperature or pH control ; and with the KM meter for water, steam, air, gas, oil and other fluid flows.

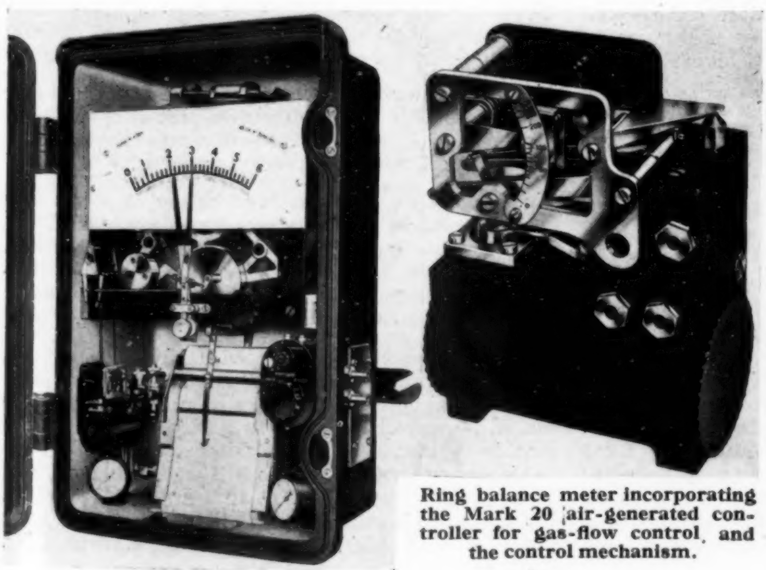
The controller equipment mounted in a standard ring balance meter for gas flow control is shown in Fig. 1, but some detailed information concerning this equipment will be of interest.

Control mechanism.—The Mark 20, mechanism shown below, embodies measuring and setting point differential gear, proportional sensitivity adjuster, bellows unit and nozzle gear, all combined in one compact unit. When integral and first derivative functions are used, for example, in the control of plants whose lag characteristics are such that proportional or proportional and integral control are unsatisfactory, they are provided with separate needle valve sensitivity settings, so that it is possible to adjust independently and instantly the proportional, integral and first derivative sensitivities, to provide optimum corrective signals for the type of plant under control.

Sensitivity adjustment ranges.—Integrating times between 10 seconds and 20 minutes are possible, with infinite adjustments between these extremes. Proportional band setting can be varied from 0–650%. A clear scale is provided for this purpose. The range of adjustment for the derivative function is in the order of 120–1. The control mechanism, relay unit and the pressure gauges to show " supply " and " control " air pressures are fitted inside the meter case.

Control accuracy.—The control mechanism will detect a deviation of less than $\pm 0{\cdot}2\%$ of the maximum scale reading and will move the diaphragm valve or other regulating device accordingly. The final results will depend upon the plant characteristics, the disturbances to which the plant is subjected and the type of regulator used.

Air supply.—For steady conditions : 3 cu. ft. of free air per hour at any pressure between 20 and 100 lb./sq. in. The air consumption increases with the magnitude and frequency of the disturbances which the controller is called upon to correct. An average maximum consumption of approximately 10 cu. ft. of free air per hour can be assumed.



Ring balance meter incorporating the Mark 20 air-generated controller for gas-flow control and the control mechanism.

Power relay unit.—This is of the non-bleed type and has adequate capacity to ensure rapid response of the control valve. The same unit houses the " automatic-to-manual " change-over valve and forms the distribution manifold for the air supply. Change-over from automatic to manual control or vice versa, can be made swiftly and smoothly without reaction on the plant, by turning the changeover knob and adjusting the pressure regulator. The same air pressure regulator provides the means of effecting manual control.

Combined air filter and moisture sump.—This is mounted on the measuring instrument and placed in the air-pressure supply line to the controller. This unit ensures

the essential supply of clean dry air to the controller and must be drained as frequently as may be necessitated by the condition of the raw air supply available.

Control valves.—A variety of control valves are available for direct, pilot or instrument operation such as the Mark 20 controller. They are made in various sizes from ½–8 in. Valve body flanges are drilled to British Standards and in accordance with the working pressure in the line.

The "Autolec" Electrode Steam Raiser

INTERESTING equipment for the rapid raising of steam is the "Autolec" electrode steam raiser designed and constructed by Messrs. G. W. B. Electric Furnaces Ltd. This equipment, which is shown in Fig. 1, conserves space, reduces noise and results in improved working conditions owing to the absence of flues, chimneys, coal stores, etc. and obviates the need for ash removal services. Steam may be raised within 5–10 mins. of switching on, the boiler requires no attendance and can be switched off for long or short periods, saving considerably in fuel cost and maintenance.

A special feature of the Autolec boiler is that the whole equipment, comprising boiler, water pump, feed tank, circuit breaker and automatic control gear is mounted on a totally enclosed stand, forming a compact self-contained unit. This boiler is claimed to have an efficiency of 97–98% and is completely automatic in operation. There are no complicated mechanisms, or adjustable platform carrying electrodes or insulator shields, thus it is impossible to cause damage by careless operation. Such a boiler has many applications, particularly as it can be placed where the steam is required.

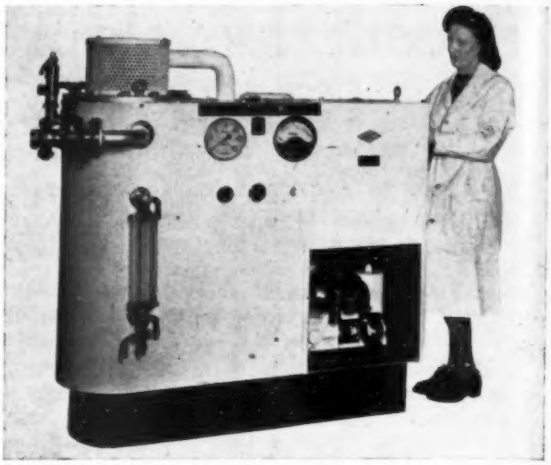


Fig. 1.—A compact self-contained unit for raising steam.

Staff Changes and Appointments

DR. C. DANNATT, O.B.E., M.C., M.I.E.E. has been appointed chief electrical engineer of the Metropolitan-Vickers Electrical Co., Ltd. in succession to Mr. G. A. Juklin who has resigned. Dr. Dannatt graduated from Armstrong College, Newcastle-on-Tyne, in 1921, in which year he joined Metropolitan-Vickers as an apprentice, and subsequently took charge of the electrical and magnetic section of the research department. His activities have been mainly concerned with engineering investigations and he is a recognised authority on electrical measurements especially in relation to magnetism and the behaviour of dielectrics. He was awarded the degree of Doctor of Science by the University of Durham in 1936. In 1940 he was appointed to the Chair of Electrical Engineering, but continued part-time activities with Metropolitan-Vickers and returned to the Company in 1944 as assistant to the chief electrical engineer; in the following year he was appointed deputy chief electrical engineer.

MR. W. W. FRANKLIN, A.M.I.M.E., has been promoted to the position of chief engineer of Davy & United Engineering Co., Ltd. on the retirement of Mr. A. Poole, M.I.M.E., who has been 40 years with the Company, 16 of which as chief engineer. Mr. Poole is remaining with the Company as a whole time consulting engineer. Further promotions following the retirement of Mr. Poole are: MR. W. CRAIG, A.M.I.M.E., to assistant chief engineer in charge of sectional rolling mill design including blooming and slabbing mills; MR. W. H. GOODLAD to assistant chief engineer in charge of flat rolling mill design, including auxiliary equipment; MR. J. G. FRITH, A.M.I.M.E., to assistant chief engineer in charge of the design of hydraulic machinery; and MR. R. BALLANTYNE, B.Sc., A.M.I.M.E., is appointed drawing office manager.

MR. CYRIL F. UWINS, O.B.E., A.F.C., has been appointed to the board of directors of the Bristol Aeroplane Co. Ltd. Mr. G. S. M. White relinquishes the position of Divisional Managing Director (Aircraft Division) and Mr. W. R. Verdon Smith that of Head Office Director, both being appointed Joint Assistant Managing Directors in succession to the late Mr. H. J. Thomas. Mr. Uwins succeeds Mr. White as Divisional Managing Director (Aircraft Division).

MR. R. M. PARRY has been elected a member of the board of directors of British Driver-Harris Co., Ltd., Manchester, nickel and nickel alloy specialists and manufacturers of the well-known range of "Nichrome" resistance materials, and has been appointed assistant managing director of the Company.

MR. J. P. LEWIS has been appointed by Messrs. Edgar Allen & Co., Ltd., to an executive post at the Imperial Steel Works, Sheffield, in connection with the production of their well-known engineering products.

MR. G. N. GEE, who has been acting as a tool steel special technical representative for Edgar Allen & Co., Ltd., with no specific limitation of territory, has been appointed special technical representative in the southern half of England. His northern boundary will run roughly across England, north of Birmingham.

MR. B. B. GREEN, who succeeded Mr. G. Hallam, as Edgar Allen representative in South Yorkshire, is, in addition, taking over the work carried on by the late Mr. H. Woodhead, in connection with the sale of crushing machinery, etc., to collieries. Most of this work will be in his present territory, but he will, when necessary, visit areas further afield. MR. A. G. GRIFFITHS has joined Mr. Green as his assistant, and will be available for work similar to that of Mr. Gee, but in the area north of Mr. Gee's boundary.

Mr. Leslie Gamage, M.C., Joint Managing Director of the General Electric Co., Ltd., has been re-elected Chairman of the British Export Trade Research Organisation, for the ensuing year. Sir Percy Lister, of R. A. Lister & Co., Ltd., is succeeded as Deputy Chairman by Mr. John Ryan, M.C., of Metal Box Co., Ltd.

Sir Frederick Leggett, C.B. has been appointed Chairman of the London and South Eastern Regional Board for Industry. Sir Frederick has had a long association with questions of industrial relations. He was Chief Adviser on industrial relations to the Ministry of Labour and later became Chief Industrial Commissioner. He was the British Government representative and member of the Governing Body of the International Labour Office and was Chairman of that body from 1936–37.

Mr. F. S. Tredinnick has been appointed Registrar of Companies by the Board of Trade in succession to Mr. P. Martin, who has retired.

Mr. D. E. Bunce has been appointed secretary of James Booth & Co., Ltd., Birmingham on the retirement of Mr. R. Franklin who will take over the position of Comptroller.

Mr. E. G. Pigott has been appointed by William Gray & Co., Ltd., Shipbuilders, West Hartlepool, to take charge of the metallurgical department at their Central Marine Engine Works. Mr. Pigott, who has resigned the position of chief metallurgist, Phoenix Steel Tube Co., Ltd., West Bromwich, to take up this new appointment, is author of the well-known textbook on "The Chemical Analysis of Ferrous Alloys and Foundry Materials" published in 1942 by Chapman & Hall, Ltd. We understand that a new and greatly enlarged edition of this book is now in the press.

Mr. A. Ramsey Moon has resigned his position as director of the British Welding Research Association, to take effect on August 31st next. Mr. Moon has been largely responsible for the development of the Welding Research Association, first as secretary of the Institute of Welding and director of research under the Welding Research Council, and for the past two years, since the formation of the Welding Research Association, as its director.

Mr. G. M. Menzies, managing director of the North British Steel Foundry, Ltd., has been appointed a director of the head office board of the General Accident Fire and Life Assurance Corporation.

Dr. D. W. Davison, F.Inst.P., of the physics staff of the Brown-Firth Research Laboratories, has been appointed Senior Research Officer in the Research School of Metallurgy at the University of Melbourne, where he will join a team working on various aspects of the physics and crystallography of ferrous and non-ferrous metals under Professor J. Neill Greenwood.

Mr. W. H. Greaves has joined the research and technical development department at Messrs. Stewarts and Lloyds, Ltd., Bilston.

Mr. F. L. Smith has been appointed chief technical engineer in charge of the central engineering department of Messrs. Dorman, Long & Co., Ltd.

Mr. Herbert Beresford has been appointed secretary to Messrs. Thos. W. Ward, Ltd., in succession to Mr. Walter Johnson who has resigned after serving the company for 59 years, 27 of which he held the secretaryship.

Mr. A. J. Crawford has been appointed manager of the Newcastle-on-Tyne Office of Metropolitan-Vickers Electrical Co., Ltd., and Mr. J. B. Hartley, M.C., M.I.E.E., manager of the Company's Manchester Office. They have succeeded, respectively, Mr. H. Paterson, M.I.E.E. and Mr. C. Peterson, who recently relinquished their duties. Mr. Crawford joined the British Westinghouse Company as a school apprentice in 1912 and subsequently gained experience in various commercial departments of the firm. In 1925 he transferred to the Company's Glasgow Office and remained until last year, when he was appointed assistant manager at Newcastle. Mr. Hartley joined the British Westinghouse Company in 1913. In 1919 he became sales engineer in the plant department of the Company, and two years later he transferred to the Manchester Office. In 1931 he became chief assistant to the District Office manager and was appointed assistant manager last year.

Honours and Awards

The conferment of a knighthood on Dr. Andrew McCance, F.R.S. will be well received in steel circles, especially in the Scottish steel industry, with which he has been closely associated for many years. In 1940 he was awarded the Bessemer Gold Medal of Iron and Steel Institute for his services in connection with the application of science to the iron and steel industry. In 1942 he was appointed a member of the Advisory Council of the Committee of the Privy Council for Scientific and Industrial Research and the following year he was elected a Fellow of the Royal Society. When the British Iron and Steel Research Association was formed in 1944 he was appointed its first chairman.

Dr. McCance is a director of the Steel Company of Scotland, Limited, Lanarkshire Steel Company, Limited, Smith & McLean, Limited, Metallurgical Products, Limited, and other companies. He is a Fellow of the Institute of Physics, and an Associate of the Royal School of Mines. In 1944 he was made a Justice of the Peace for Lanarkshire.

Sir James Lithgow, Bt., receives the C.B. for his services. Sir James is chairman of the Steel Company of Scotland, Limited, William Beardmore & Company, Limited, managing director of Lithgows, Limited, and a director of Colvilles, Limited, Richard Thomas & Baldwins, Limited, and many other companies.

Dr. T. P. Colclough receives the C.B.E. for services as Technical adviser to the Ministry of Supply (Iron and Steel Control) during the war. He is now technical adviser to the British Iron and Steel Federation and the Iron and Steel Board.

Mr. James Carson, who has been awarded the O.B.E., is a director of Stewarts and Lloyds, Limited and lately a director of New Crown Forgings, Limited, Glasgow. Mr. J. W. Myers, awarded the M.B.E., is manager of iron and steel foundries of Vickers-Armstrongs, Limited,

A New Mechanised Forge

Continued from page 178

In a machine of this type, primary consideration must be given to protection from hammer shock. For this purpose the machine is equipped with dual-purpose oil/air shock recuperators, fully protecting the parallel hoisting motion and ensuring positive gripping at the instant of impact. A specially designed self-adjusting mechanism compensates for the elongation of the work-piece during forging.

Furnace Operation

Ingots are charged by the manipulator into either of the primary preheating chambers which operate in regular sequence. Whilst the ingots in one chamber are gradually being heated from 0°–600° C. the others in the second chamber have reached and are being maintained at the desired initial temperature of preheat.

The alternate cycles are adjustable in relation to the production requirements, but by the time all the heated ingots have been separately transferred at regular intervals of time from one primary preheating chamber to the secondary preheating chamber the others in the second primary chamber are ready for withdrawal.

In this manner the secondary preheating chamber which heats the steel from 600°–1,000° C., is fed at the optimum rate by the manipulator. The sequence of flow is similarly maintained between the secondary preheating chamber and the tertiary heating chambers. Upon the attainment of the desired maximum temperature each ingot is transferred by the manipulator to the hammer for the forging process. Semi-forged products which need reheating are subsequently brought back to temperature in one of the tertiary heating chambers. Continuity of flow from the ingot stock-yard to the finishing bay is consequently achieved and maintained.

Hydraulic Operation of Furnace Doors

A simple and efficient system, hydraulically operated and installed by Vickers Armstrong, Ltd., Newcastle-on-Tyne, is employed for raising and lowering the furnace doors. The system consists of a hydraulic power unit directly coupled through a control standard and individual control valves, to the requisite hydraulic rams operating each door independently. The hydraulic medium is a heavy grade of mineral oil.

Two separate power units are supplied, each comprising a " VSG " auto pump, fitted with internal springs for control, and driven by an electric motor with appropriate starter; each pump is of sufficient capacity to operate four doors simultaneously, the other acting as standby.

The pressure discharge from either pump is led into a manifold embodied in the control standard, and thence to the individual control valves, so that by operating the appropriate handle, pressure fluid is led through the control valve to the hydraulic ram concerned, which is direct coupled to its own furnace door through ropes and chains with the necessary pulleys. The rams have a ratio of 2–1, i.e., their stroke is only half the lift of the doors.

A forward movement of the appropriate handle raises any individual furnace door at a stipulated speed, whilst the reverse movement of the handle lowers the door at the required speed.

The automatic control of the " VSG " pump ensures that the doors remain in the open position whilst their respective control handles are in the forward position, and on the reverse the doors are automatically arrested before reaching the closed position, by a throttling device on the hydraulic cylinders. This ensures a cushioned seating obviating shocks and damage to the furnace linings.

The operator is thus relieved of the necessity of exercising care in controlling the speeds of lifting and lowering and can deal with the individual furnaces as soon as the " open " or " close " signals are given, irrespective of whether or not the operations already in hand have been completed.

This complete installation, with its many unique features, is operating 24 hours a day of each 5-day week, and is thus helping to meet the heavy demand for high-grade alloy steel forgings, while, at the same time, providing improved conditions for the operators.

Philips Lamps Ltd. to become Philips Electrical Ltd.

On September 1, 1947, Philips Lamps Ltd. will change its name to " Philips Electrical Limited." Behind this announcement is a story of the remarkable advancement of a small company founded in this country in 1925, with a staff of 40 people, to market electric lamps and X-ray tubes. Its headquarters were in Wilson Street in the City of London. In 1926, the Company took over a lamp factory in Harlesden, London, which was remodelled to make the " Philips " lamp. More commodious premises in Charing Cross Road were then occupied as headquarters.

Further developments were made in 1928 when the Company introduced the first all mains radio receiver to be marketed in this country. In the same year, a factory was opened in Mitcham, Surrey, where was commenced the production of a range of domestic radio receivers, car radios, radio-gramophones. This factory was the first of a group of factories set up in various parts of England and Scotland. In 1938, for instance, works were opened in Blackburn, where are manufactured fluorescent tubes for discharge lighting, filaments for lamps, diamond dies for wire drawing and component parts for radio sets. A factory was opened in Hamilton in 1945 for the manufacture of radio sets and components, where extensions are now in hand. By 1946, the demands of these factories for machinery to meet their special needs had assumed such proportions that the usual sources of supply became inadequate. To meet these demands works were opened in Southport which is doing much to keep production flowing smoothly throughout the various factories of the Company.

In addition to the Company's expansion in radio production was the rapid development of industrial equipment of all kinds. In 1933, a department known as Philips Industrial was created to design and market high-quality welding apparatus and appliances.

In 1939, new headquarters in Shaftsbury Avenue were occupied, in which nearly a thousand people administer the Company's business. To-day, the Company employs over 11,000 people in Great Britain in its factories, offices and research laboratories and the all-embracing title of Philips Electrical Ltd. is more in keeping with its activities.

WE are greatly encouraged to note that recently two of the foremost organic chemists in the country have publicly expressed their belief in the fundamental importance of analytical chemistry. The President of the Royal Society, by his remarks at the dinner of the Society of Public Analysts and Other Analytical Chemists, showed clearly that he approved of the recent move for the more explicit teaching of analytical chemistry, as a branch of chemistry in its own right, in the Universities. Too few of the institutions of University status in this country accord that recognition which the subject deserves. One of the direct consequences is undoubtedly the neglect of analytical chemistry as a field of pure research, with the unfortunate result that recent advances in the theory of analytical chemistry seem to originate largely outside this country. Professor Heilbron, in the first Henderson Memorial Lecture, comments in passing : " Henderson wisely retained the Dittmar tradition which provided a thorough training in analytical chemistry." He who runs may not always be able to detect the connection between analytical chemistry and the diverse branches of chemistry. That two such acute minds have placed before us, almost simultaneously, glosses on this connection with the branch of chemistry which, to the casual observer, appears primarily concerned with synthesis, should give us pause, ct least for the few moments necessary to observe and to note the link. We trust that this means that the auspices are favourable for an advance to a commanding position by this fundamental branch of science.

Polarographic Determination of Zinc in Aluminium Alloys

By W. Stross

(Continued from page 166)

The first part of this article dealt with three methods for determining zinc ; (1) Using the centrifuge; (2) without using the centrifuge; and (3) on a micro and semi-micro scale. A number of points concerning each of the methods is considered more fully in the portion of the article which follows.

Remarks

1. The procedure with the centrifuge is particularly suitable for dealing with a large number of samples as a centrifuge of the type illustrated in Griffin and Tatlock's catalogue on page 189 under number B.19–150, carries 42 tubes of the 6 × ¾ in. type. No adaptor is required, if seven tubes at a time are placed in one bucket. With such an instrument, one operator can analyse 42 samples in an 8-hour shift with ease and without any help, whilst, with the help for about four hours of one semi-skilled assistant, up to 100 samples can be analysed in 8 hours. With a single sample, or with very small batches, the method is comparatively long, due to the necessary number of runs of the centrifuge.

This applies even more if the centrifuge is not fitted with a brake, which device considerably shortens the time required for each run.

For a small number of samples the sinter funnel method is more suitable. By the use of T-pieces 6 sinter funnels—probably even more—can easily be operated from one water jet pump. If many samples are to be analysed simultaneously using one pump, it is useful to place ordinary single-way stopcocks or spring clips in such a way that the suction can be concentrated on one or more funnels, if the filtration in them should slow down more than in the others. This is, however, rarely the case as the liquid usually disappears nearly instantaneously from the surface of the funnel.

The time for the analysis of 1 to 6 samples by this technique is from 30 to 90 minutes. The procedure can be speeded up if one precipitation only is made, using 1 ml. 1 : 1 sulphuric acid and 1 ml. chlorate solution, followed by 8 ml. of the caustic solution, so as to obtain the usual concentration of salts and caustic ; under these conditions the calibration graphs obtained in the normal way can be used. The results are slightly too low, but only by a few per cent. of the total zinc present, which will be considered insignificant in some cases, particularly in the lower range, compared with the gain in speed.

2. The chloride plated silver wire anode as proposed

recently[9] can be used with great advantage. A sensitivity at which 4 microamps correspond to the whole width of the paper, i.e., the sensitivity "4" of the Tinsley instrument, covers the range down to about 0·02%, thus a higher sensitivity will hardly ever be required for routine purposes. At this comparatively low sensitivity the danger of oxygen diffusing back into the solution is negligible if the polarographic recording is carried out immediately after the de-aeration, even without using a water seal, a stopper or a "gas blanket." Consequently, with the silver wire anode, no special cells are required but the test tubes in which the final filtrate is collected can be used directly, after passing hydrogen or nitrogen for a few minutes. The saving in time and mercury is considerable.

As long as the surface of the wire is free from mercury, the half-wave potentials are shifted to the negative by about 0·2 volts as compared with the usual bottom mercury anode pool; if the silver wire becomes amalgamated—which happens easily in routine*—this potential difference becomes smaller; otherwise the amalgamation does not seem to have any detrimental effect. We have been using the silver wire electrode not only for zinc but also for lead determinations, the latter in a hydrochloric acid medium, with the use of hydroxylamine and thiocyanate.[3]

The de-aeration is facilitated if not more than about 10 ml. of the final filtrate are used.

3. It has been recommended above to make up the final solution to 40 ml. when using the sinter funnels, as compared to 25 ml. in the centrifuge technique. The reason is that, using the sinter funnels, the results tend to be slightly too low if the final volume is 25 ml. Under the conditions as laid down, correct results were obtained. This seems to be due to the greater volume of washing water which can be used, possibly also to the greater quantity of caustic used for the precipitation.

Although the wave height, of course, decreases with the greater dilution, the decrease is smaller than in proportion to the dilution, probably due to the smaller overall molecular concentrations of the solutions. The calibration obtained under the conditions of the first technique is therefore not applicable to the second, and vice versa.

4. The liquids collected after the centrifuging, and likewise those after the filtration through the sinter funnel (except, of course, the first liquid after the alkaline attack) are generally coloured and slightly turbid as a little of the hydroxides of copper, iron, etc. may pass through the filter, or remain in the centrifugate, in a colloidal form. The paper pulp added before the final filtration coagulates and/or retains these hydroxides and the filtrates obtained finally are colourless and quite clear.

In polarography, the presence of a precipitate in the solution would not in itself interfere, although the author's impression is that graphs generally tend to improve in shape and reproducibility if precipitates are filtered off. In the case of the zinc determination, however, the copper hydroxide is somewhat polarographically active so that without the final filtration, much counter current may be required. In addition, small quantities of iron hydroxide may also be present and they may make the zinc wave slightly higher than it should be, the wave of ferrous iron being very near to that of zinc in alkaline medium. It was indeed, generally found that, if a solution was divided into two parts after making up and mixing, and one part polarographed unfiltered, the other unfiltered, the zinc waves were nearly always higher by a few divisions in the unfiltered condition. This is, however, not due to absorption by the filter paper, as after the first filtration the solution can be filtered repeatedly, using each time large quantities of paper pulp and several layers of filter paper, without a further reduction of the wave in the subsequent filtrates.

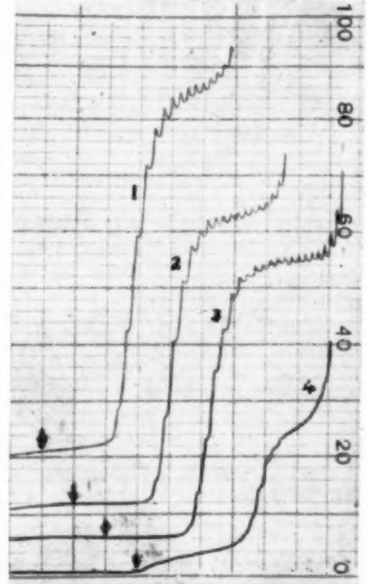


Fig. 2.–Graphs recorded on solutions of alloys of different zinc content obtained by the method described in this paper.

A Tinsley polarograph with ink recorder was used. The arrow indicates the potential of 1.2 volt, using the silver chloride - silver anode. The sensitivities used varied from 100 to 2; sensitivity 100 on the Tinsley instrument means that a current of 100 microamps produces a deflection over the full width of the paper, i.e., 100 divisions, whilst at sensitivity 2 the same deflection (100 divisions) is produced by a current of 2 microamps. The dropping rate of the capillary used was 40 seconds for 10 drops at 1 volt applied, in potassium chloride solution. Sensitivities used No. 1, Sens. 4; No. 2, Sens. 20; No. 3, Sens. 100; No. 4, Sens. 2. A damping of 4,000 microfarad was used in all cases; two accumulators were used.

5. It has been stated repeatedly that the zinc wave obtained in alkaline solution is not sufficiently well defined for quantitative purposes. It may therefore, seem useful to publish a few graphs obtained at various sensitivities by the above technique (Fig. 2).

From these it would appear that the wave, whilst possibly not ideal, is quite suitable for practical purposes and that the advantages of the described technique outweigh the deficiency in quality of the wave.

The wave could be improved—according to an unpublished suggestion of M. Spálenka—by adding ammonium chloride-ammonia mixtures. It would then, however, be necessary to add measured volumes of such a mixture to measured volumes of the filtrate; the addition of this mixture before making up to the mark and filtering may bring copper and nickel back into solution if the ammonia concentration is sufficiently high to improve the wave and in presence of gelatine a peculiar purple colour—similar to, or possibly identical with, the biuret reaction for protein—may be produced with subsequent distortion of the zinc wave. It is not thought that, for routine purposes, the improvement of

* The amalgamation can easily be avoided if the end of the wire spiral is not placed so near to the tip of the capillary as originally proposed,[9] but at about 1 in. distance from the tip.

9 J. J. Lingane, *Ind. and Eng. Chem., Anal. Ed.*, 1944, **16**, 329.

the wave shape outweighs the disadvantage of two further volumetric measurements per sample and of a considerable further dilution of the final solution with regard to the alloy concentration.

6. Whilst samples of up to about 15% zinc can be analysed by this technique if the low sensitivities of the instrument are used, it is useful to restrict the number of sensitivities used for routine purposes. By taking smaller weighings, and making the weight of the sample up to 500 mg. with High Purity Aluminium, all alloys within this range can be covered by using sensitivities 4, 20 and 40* only, thus considerably simplifying the calibration procedure.

7. If alloys with about 10% of magnesium are to be analysed by the sinter funnel technique, it is advisable not to take larger samples than 250 mg. (plus 250 mg. high purity aluminium) and to stir half or one accelerator into the solution before the first filtration, in addition to using the usual paper pulp pad: 1 ml. of water should then be added to the acid. Without these precautions the quantity of magnesium hydroxide on the filter tends to become unmanageable.

8. The pressure applied from below effectively prevents any liquid permeating the sinter plate: this technique may be useful also for other purposes.†

The two-way cock II not only makes it possible to release the pressure but also prevents, if used according to description, in case of a small leak of the other two-way cock, that mercury is sucked back from the manometer, if the stopcock III is not opened in time.

9. It is important to avoid pouring hot and too strong caustic soda solution on the paper pulp, since this may give rise to erroniously high and distorted zinc values.

10. In an alkaline medium it is often advantageous to use sulphite instead of expelling the oxygen by passing an inert gas. Attempts at using sulphite here were, however, unsuccessful. In the final filtrate the action of sulphite is poor, probably because of the absence of copper[10]; if the sulphite was added to the unfiltered solution, the results sometimes became erratic, possibly due to some ferrous iron going into solution (see remark 4).

11. The porosity of the sintered funnels remains unimpaired practically indefinitely if they are cleaned by first taking off the bulk of the pad cum precipitate mechanically, then sucking through a little dilute aqua regia and water, and finally sucking through water in the inverted position, as shown in the sketch B of Fig. 1. If compressed air instead of water is used in a metal jet suction pump, the much higher rate of suction makes the simple rubber sheet (approximately $\frac{1}{4}$ in. thick) a sufficiently tight fit to ensure rapid washing. The manipulation of washing in this position, as well as that of preparing the filter pad, and the washing with acid and water, is speeded up considerably by using the perforated rubber sheet in the positions as shown in the sketches B and C respectively.

12. As mentioned before[6] solutions obtained with alloys of high silicon content (e.g., 10% and more) may become turbid after some standing; this does, however, not interfere. The precipitate can be filtered off if desired, this is, however, not necessary.

The author wishes to thank the directors of Messrs. International Alloys Ltd., Aylesbury, in whose laboratories these experiments were carried out, for permission to publish.

* See caption to Figure 2.

† The author is not certain whether this has not been suggested elsewhere before; he could, however, not find any publication referring to it.

10 M. Spălenka, *Z. anal. Chem.*, 1943, **126**, 57.

Miscellaneous Microchemical Devices—XII

A Simple All-Glass Syringe Pipette

By J. T. Stock and M. A. Fill

Chemistry Department, L.C.C. Norwood Technical Institute, Knight's Hill, London, S.E. 27.

IN microchemical analysis it is frequently necessary to make small, measured additions of reagents. For this purpose, the syringe pipette shown in Fig. 1 (*a*) is very convenient. Being entirely of glass, the pipette is particularly suitable for handling bromine, nitric-acid and other corrosive liquids. Glass tubing and rod are the only materials used in construction, which requires but elementary skill in glassblowing.

Though pipettes of bore as small as 1 mm. or as large as 5 mm. have been satisfactorily constructed, the optimum size is from 2–3 mm. The bore of the tubing used in construction should be truly circular and without appreciable taper. Selection is best made by viewing the cut ends under a microscope equipped with an eyepiece micrometer scale.

Two pipettes may be prepared from a selected piece of tubing some 25 cm. long. To facilitate entry of the plunger, the ends of the latter are slightly flared. The tubing is then heated in the middle and, after thickening up, is drawn out. When cold, the tubing is nicked at the middle of the narrow portion and broken, thus forming two pipettes. These may be graduated as desired.

To construct the plunger, glass rod which slides easily, but without much shake, within the pipette is used. (The diameter of the rod need be only a few tenths of a millimetre less than the bore of the pipette). Having slightly thickened up one end of the rod, as shown at Fig. 1 (*b*), the thickened end, which forms the plunger, is carefully ground into the flared end of the pipette until the plunger just enters the bore. Very fine emery powder and water are used for this operation, which may be performed either by hand or preferably by holding the stem of the plunger in the chuck of a slowly-rotating electric stirrer and then applying the flared end of the pipette. Taking care not to jam the plunger in the lower convergent portion of the pipette, grinding is continued until the plunger slides the whole length of the parallel portion of the pipette, as shown at Fig. 1 (*c*). All abrasive is now thoroughly washed away and the parts are dried. A small sphere is then formed upon

the stem of the plunger, as shown at Fig. 1 (*a*). This acts as a stop, preventing the plunger from being depressed too far and thus becoming jammed during operation of the device. If desired, the sphere may be ground into the flare of the pipette. A small, flat, knob at the head of the plunger stem completes the construction.

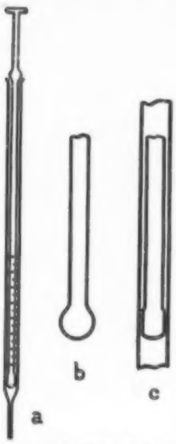


Fig. 1.—Glass syringe pipette, showing construction of plunger.

To use the device, the upper part of the pipette should be held between the ring-finger and thumb, whilst the plunger is operated by gripping the stem beneath the knob between the index- and middle-finger. The liquid to be delivered is then drawn in through the jet. Once the plunger head becomes wetted, little or no leakage occurs and liquid issues from the jet only when the plunger is depressed. Several small quantities of liquid may thus be conveniently dispensed from a single filling of the pipette.

If carefully made, the device may be used to dispense volatile, mobile liquids such as ether. A minute mercury seal above the plunger may also be employed, thus completely sealing the latter against leakage. This modification is particularly useful when it is desired to handle very dense liquids, such as mercury itself. No alteration in construction is necessary. With the plunger fully depressed, the jet of the pipette is thrust deeply into mercury so that the latter enters and makes contact with the plunger, the air escaping between the latter and the walls of the pipette. Having drawn in a little more mercury by slightly raising the plunger, the latter is forcibly depressed. In this manner a small amount of mercury, sufficient to constitute a seal, is forced past the plunger and remains immediately above the latter in the annulus formed by the bore of the pipette and the stem of the plunger.

The device may be readily adapted to suit the micro-reagent bottle previously described.[1] This modification

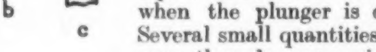


Fig. 2.—Micro-reagent bottle fitted with syringe pipette.

is depicted in Fig. 2, whilst details of construction are given in Fig. 3. The bottle-cap is constructed from tubing of 5–6 mm. bore. A length of about 18 cm. is cut, the ends are slightly flared and flanges are formed 4 cm. from either end, as shown at (*a*) in Fig. 3. The flanges may be conveniently formed by heating the tubing in a small, hot, blowpipe flame. Rotating steadily, the ends of the tubing are slowly forced together until the flange forms. After flanging, the tubing is heated at its middle point and is drawn out. When cold, the narrow central portion is cut out, leaving a pair of bottle-caps, each as shown at (*b*).

The pipette is constructed from tubing of 2–3 mm. bore which is selected as previously described. One end is flared, whilst the other is drawn out to form a jet, as shown at (*c*). The pipette is then sealed on squarely to the bottle-cap as shown at (*d*). Care should be taken that the parallel portion of the bore of the pipette suffers no constriction during the sealing operation.

Glass rod selected as before is used to construct the

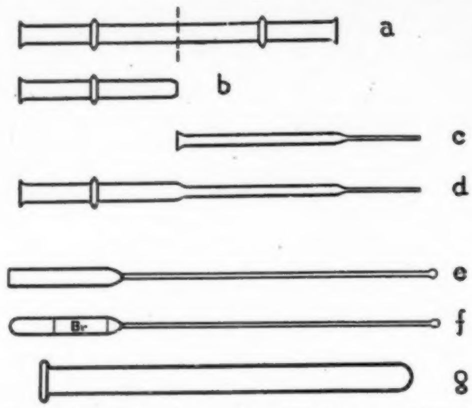


Fig. 3.—Details of construction of micro-reagent bottle.

plunger and stem. One end of a suitable length is thickened up and ground into the pipette as described above. A handle constructed of 5–6 mm. bore tubing is then sealed to the upper end of the plunger stem, as shown at (*e*). The written or typed identification label is rolled up and slipped into the open end of the handle; the latter is then closed by fusion, as shown at (*f*). Finally, the conical portion of the handle is ground into the flare of the bottle-cap.

Container (*g*) is made from tubing, the bore of which accommodates the bottle-cap without excessive shake. The device is completed by grinding the underside of the flange of the bottle-cap into the flare of the container.

1 Stock, J. T., and Fill, M. A., *Metallurgia*, 1946, **33**, 323.

Heat-Treatment Plant for Turkey

WILD-BARFIELD ELECTRIC FURNACES LTD. have received an order for the supply of heat-treatment equipment to the aero engine factory of the Turk Hava Kurumu, Ankara, which is to manufacture the De Havilland Gipsy engines. The plant consists of modern electric furnaces of the "Heavy-Hairpin" type for general heat-treatment. Vertical forced air circulation furnaces with the patented charge progress recorder are to be used for the tempering of steel parts and the heat-treatment of light alloys. Low temperature electric ovens are being supplied for paint drying and other applications.

Errata

JULY ISSUE.—In the first column on page 113, under the sub-heading "apparatus," "rod E" should read rod L, as indicated in Fig. 1. The word "design" in the caption to Fig. 5 on page 114 should read diagram. The illustrations over the captions (*a*) and (*b*) Fig. 11 should be transposed.

The caption to Fig. 3 on page 127 reads "The most efficient change is from (*a*) (Steel) to (*b*) (magnesium alloy)"; this should read from (*a*) to (*d*).

Transpose the words "unetched" and "etched" in the captions to Figs 5 and 6 on page 151. The last line, first paragraph of second column on page 152 reads by a 14-hour temper at 790°C."—the temperature should read 760°C.

Effect of Nickel on Physical Properties and Thermal Characteristics of Cast Chromium-Molybdenum Steels

By N. A. Ziegler and W. L. Meinhart

INVESTIGATIONS of the characteristics and properties of cast chromium-molybdenum steels containing 0·3% carbon, 9% chromium and up to 1·5% molybdenum, have shown that the thermal sluggishness and hardenability of this group of steels increases in proportion to the percentage of carbon, chromium and/or molybdenum. As one of the problems in improving weldability of a given steel is to reduce its carbon content and to add some alloying element which will strengthen it and at the same time have a minimum effect on developing suppressed transformations, it was decided to thoroughly investigate the effect of nickel up to 2% on the thermal and physical properties of the cast chromium-molybdenum steel previously investigated.

A series of 36 nickel-bearing chromium-molybdenum steels were prepared in a basic lined high frequency induction furnace and cast into green sand moulds. These steels were divided into four groups containing 2·5, 5, 7 and 9% of chromium, and 0·5, 1 and 1·5% of molybdenum respectively. Each of the four groups was sub-divided into three sub-groups containing about 0·5, 0·15 and 0·30% carbon, and each sub-group was composed of three steels containing 0·5, 1 and 2% of nickel. Before testing each steel was heat treated by normalising at 950° C., air quenching from 840° C., and tempering at 675° C. The tensile properties and Charpy impact resistance was determined for each steel.

All the steels were subjected to thermal analyses by means of a differential, photographically recording dilatometer, using specimens heated in vacuum to 1,000° C. in 2 hours and then cooled to room temperature at an average rate of (*a*) 3·2° C. per minute and (*b*) 50° C. per minute. Every dilatometer specimen after testing was tested for Vickers hardness and micro-examined.

TABLE I.—COMPOSITION OF CAST CHROMIUM-MOLYBDENUM STEELS.

No.	C	Cr	Mo	Ni
1	0·2	5	0·5	0
2	0·1	1·5	0·5	0
3	0·1	1·5	0·5	1
4	0·1	2·5	0·5	0
5	0·1	2·5	0·5	1
6	0·1	5	0·5	0
7	0·1	5	0·5	1
8	0·1	7	1·0	0·5
9	0·1	7	1·0	1
10	0·1	9	1·5	0
11	0·1	9	1·5	1

It was found that nickel had a rather pronounced strengthening effect on the types of steels tested, without reducing to any appreciable extent the ductility and impact resistance. In steels containing 0·05% and 0·15% carbon and up to and including 5% chromium, the strengthening effect of 1% nickel was about equal to an increase of 0·15% in the carbon content, but its effect on reducing ductility and impact resistance was much less. When the percentage of chromium was increased beyond 5% and up to 9%, the effect of nickel became less pronounced. Likewise, the effect of nickel was stronger in steels with less than 0·15% carbon than in those with over 0·15% carbon. The addition of 1% of nickel to steels containing 0·1% carbon of the type tested produced physical properties similar to those of 0·2% carbon steels. In general, nickel increased the thermal sluggishness of chromium-molybdenum steels but to a lesser degree than carbon in amounts necessary to develop similar strength.

On the strength of the results obtained, steels of similar composition to those already tested, Table I, were subjected to actual welding experiments, after being heat treated, tested and subjected to dilatometric analysis. Welding was carried out using standard chromium - molybdenum electrodes. Vickers hardness determinations were made at ¼ in. intervals across each weld and the affected zones. The results obtained from those tests showed that the level of the hardness distribution curves across the welds and the affected zone in low carbon-molybdenum steels containing nickel was much lower than in similar steels free from nickel but containing higher carbon in amounts necessary to develop the desired strength.

Creep and corrosion resistance properties of these steels have not been studied, hence their behaviour in some specific corrosive environment or at high temperatures is at present not yet known.

From *American Society for Metals*, 1945, Preprint No. 28, pp. 1–40.

Determination of Silicon and Silica by the Gelatine Method

By Erik Hammarberg

EXPERIMENTS have been carried out, using the gelatine method, for the determination of silicon in pig iron, steel and some ferro-alloys, as well as silica in silicates. This method, which is based on the precipitation of silica in an acid solution by the addition of gelatine, is shown to give quite as correct results as the customary dehydration methods. The time necessary for an analysis of silicon in steel by the gelatine method is much shorter than for the older dehydration method, involving evaporation to dryness. When the material is readily dissolved in acids, the time for an analysis can be estimated to be 30–40 mins., excluding the time for volatiliation of the silica with hydrofluoric acid, which, in most cases, is unnecessary. Experiments on slags also show that the determination of silicon in ferro-silicon and silica in slags, especially basic slags, by means of the gelatine method, has great advantages in comparison with the current methods.

From *Fernk Annal.* **131**, 1947, 199-211.

The Development of a Turbo-Supercharger Bucket

By E. Epremian

TURBO-SUPERCHARGERS and gas turbines for aircraft are subjected to severe treatment; in addition to being required to withstand the corrosive atmosphere of combusted gases at temperatures up to 815° C., the buckets must support high stresses for prolonged periods. A number of iron-base alloys have been developed for supercharger buckets. One of these, a forgeable, machineable iron-base alloy, which has been used for this purpose, has the following nominal analysis: C 0·50, Mn 0·60, P 0·02, S 0·015, Si 0·75, Cr 13, Ni 20, W 2·25, Mo 0·65 with iron remainder. This alloy is suitable for temperatures up to 650° C.; at higher temperatures, its strength decreases rapidly with time, due to structural instability. Cold work, produced by forging at a temperature below 650° C. increases the heat-time values of tensile, rupture and creep strengths. For long time service, however, the quenched and drawn condition is stronger and more stable.

From *Can. Metals and Metallurgical Ind.*, Jan. 1947, 22–25.

To meet increasingly severe service requirements a number of materials were developed with higher alloy content. Many of these alloys were difficult to forge and machine and it became necessary to adapt the precision casting process. An alloy known as Vitallium, containing 30% Cr, 5% Mo and 65% Co, used for many years for dentures and bone surgery appliances, was used with little modification in the first cast alloy buckets. Later an improved Vitallium-type alloy was used as supercharger bucket material.

The combination of chromium and cobalt produces a solid solution matrix which is strong and stable at elevated temperatures and has good resistance to oxidation. Additions of molybdenum and tungsten increase the hot strength and hardness by both solid solution and compound formation and in order to determine quantitatively the optimum percentages of certain elements in a cobalt-base alloy for supercharger bucket application an investigation was carried out. A series of alloys was prepared in which the molybdenum was held constant at 6% and the chromium varied from 18 to 42% in 2% steps at the expense of cobalt. The carbon content was held low and small amounts of manganese and silicon were used for deoxidation.

In addition to the usual sustained-load fracture test, tensile test and hardness determinations were made from which the following general conclusions were given:—

Highest tensile strength	32–34% Cr
Highest room temperature ductility	28% Cr
Highest fracture strength at 650° C.	34% Cr
Highest fracture strength at 815° C.	20% Cr

It appears that alloys containing less than 20% chromium lack oxidation-corrosion resistance at 815° C. and those containing more than 34% chromium are too brittle. The data obtained indicate that further work

on the 20% chromium composition would be of interest, when operating in exhaust gases of leaded fuel, however, it is desirable that the minimum chromium content of the alloy be 25% for protection from intergranular attack. The study was therefore concentrated on alloys containing 25% chromium.

The effect of nickel additions was studied. Fracture tests at 815° C. were made on a series of alloys in which nickel was added in small steps at the expense of cobalt while chromium and molybdenum were held at 25 and 6% respectively. A number of tests were made with each alloy and the results indicate that the most outstanding alloy in the series contains 10% nickel. This material has the highest strength as well as the highest ductility.

The addition of tungsten or molybdenum to steels is known to promote strength at elevated temperatures, molybdenum being the more effective per unit weight. Some random preliminary tests indicated that in some instances the combustion of these two elements produced better properties than either alone and a detailed study was made using the 10% nickel alloy as a base. A series of alloys was precision cast and tested to fracture at 815 and 925° C. Tungsten and molybdenum were added to the base composition in total weight percentages of 4, 6, 8, 10 and 12. These additions were made in W/Mo ratios of 0/1, 1/3 and 1/1 to give a total of 15 alloys. The changes in the composition were absorbed by the balance of the base alloy, rather than the cobalt alone, so that the same Cr/Ni/Co proportions were maintained throughout.

The best material in this latter group, designated ×63, is shown to be the alloy containing 6% molybdenum. The next best material at 815° C. appears to be that with 4% molybdenum and 4% tungsten, which is about the equivalent of 6% molybdenum in terms of atomic per cent.

The outstanding alloy resulting from this investigation is the material designated ×63 with the following composition :—

C	Mn	Si	Cr	Ni	Mo	Co
0·4–0·5	0·5	0·5	25	10	6	Bal.

There are, however, several characteristics and properties of a promising bucket alloy which must be determined before it can be put into service ; for this reason the following additional information was obtained on this composition.

Rupture data were obtained over the range of temperatures, stresses and times that might be encountered in service.

	100 hr. Rupture Strength.	% Elon.
730° C.	18 tons/in. sq. in.	9
815° C.	13 „ „	20
925° C.	7½ „ „	16

	1,000 hr. Rupture Strength.	% Elon.
730° C.	14½ tons/sq. in.	7
815° C.	11 „ „	10
925° C.	5½ „ „	19

Tensile tests were made to determine the short-time tensile strength and ductility.

	Room Temp.	815° C.
Tensile strength	44½ tons/in.	31 tons/in.
Yield strength (0·2%)	21½ „	—
Elongation % 1 in.	5	12
Reduction of area %	5	15

Impact tests to indicate how the alloy would react under shock-loading :

Charpy. 0·250-in. sq. bars, unnotched.

Room temp.	815° C.
15 ft.-lbs.	25 ft.-lbs.

Average coefficient of thermal expansion :—

18·4 in./in./C × $^{-6}$; between 250 and 850° C.

Thermal conductivity data.

Temp. ° C.	Thermal Conductivity Watts/Cm./C.
150	0·137
200	0·146
300	0·161
400	0·174
500	0·187
600	0·200

Specific gravity at 20·8° C., 8·34 grm./c.c.

Hardness measurements :—

As cast	31 Rc.
After 16 hrs. at 815° C.	39 „
After 129 „ „ „	40 „
After 870 „ „ „	40 „
After 1152 „ „ „	37 „

Constant stress creep tests gave the following results :—

Temp. ° C.	Stress tons/ sq. in.	Duration hr.	Total Ext. mils/in.	Final rate %/100,000 hr.
650	9	2350	0·77	0·85
—	13	2707	1·886	3·66
815	4½	2463	2·52	2·5
—	3½	2463	1·94	2·3

Damping Capacity.

Temp. ° C.	% Log. decrement (Stress 7½ tons/sq. in.
24	0·092
482	0·291
650	0·234

Fatigue Strength.

Cyclic bending tests on samples with a cross section suitable for a supercharger or turbine bucket gave the following values :—

Temp. ° C.	Extreme Fibre Stress Tons/sq. in.	Cycles to crack*
650	19	390,000
	17	462,000
	12·5	764,000
	11·25	2,100,000
	11	Unbroken in 10^7 cycles.
730	17·3	496,000
	11·7	6,300,000
	9·8	Unbroken in 10^7 cycles

* Pressure of crack indicated by change in the natural frequency.

Stress Corrosion of Austenitic Cast Irons

By J. B. Urban, J. W. Bolton and A. J. Smith

STRONG hot caustic soda is a powerful corrosive towards many metals and produces embrittlement in some. Suitable grades of grey cast iron have fairly good resistance towards the corrosive effect and also are relatively free from stress corrosion deterioration. Some of the high nickel austenitic cast irons have excellent corrosion resistance towards strong caustics, even at elevated temperatures and the present investigation deals with the stress corrosion of such irons.

Samples of austenitic cast iron were immersed in 50% caustic soda solutions, boiled, using a reflux condenser, for periods up to six months and broken in impact. The results obtained were similar to those obtained with samples not exposed to caustic soda and showed that caustic embrittlement did not result when stress was absent. Other samples were loaded under standard creep test conditions and showed the austenitic irons tested to withstand stresses up to 6·7 tons per sq. in. at 175° C. without measurable flow or creep. When the creep tested specimens were tested, they showed no difference in strength and ductility when compared with unstressed specimens.

To investigate the combined effects of stress and exposure to the corrosive medium tests were carried out on the cast irons given in Table I. All specimens were cast in green sand and tested in the unmachined condition to simulate the surface conditions of the cast product as commonly used. The corrosive medium and condition chosen was 50% by weight of commercial sodium hydroxide (acqueous solution) at 140° C. Three methods of stress application used were tensile loading, cantilever loading and beam loading.

From *The Foundry*, 1946, **74**, pp. 88–90, 182, 184, 186.

TABLE I.—COMPOSITION OF CAST IRONS TESTED.

	Ordinary Cast Iron	Austenitic Cast Irons A	B	C	D
Total Carbon	3·25	2·44	2·10	2·66	2·75
Silicon	2·75	1·84	1·77	1·88	1·97
Manganese	0·58	0·90	0·74	0·92	0·98
Phosphorus	0·33	0·050	0·049	0·14	0·13
Sulphur	0·055	0·020	0·015	0·028	0·025
Nickel	—	19·82	20·61	19·86	19·09
Chromium	—	1·60	—	1·65	1·75
Molybdenum	—	0·74	0·90	0·63	0·62
Copper	—	4·10	0·06	4·55	4·33

In the tensile loading tests, the test specimen was mounted between high nickel alloy pulling bars supported at the top with a ball and socket joint and a dead load applied to the bottom. The bottom bar passed through the base of a high nickel alloy container with a watertight seal, the container being filled with the commercial sodium hydroxide solution. A heating element around the container maintained the desired temperature of 140° C. In the cantilever loading and beam loading systems the ends of the test specimens were attached to the load through a wire passing over a ball bearing mounted pulley of very low frictional resistance. By means of this arrangement, stresses on the specimens were independent of flexural changes in the supports within reasonable limits of flexure of specimens. Tests were carried out both on round specimens, 0·5 in. diameter, and specimens of rectangular cross section, measuring 1 by 0·4 in. Specimens were 8½ in. in length in the cantilever tests, and in the simple beam tests the outer knife edges were 9½ in. apart, and the centre knife edge 3½ in. from the lower fixed edge.

The tensile test results are summarised in Table II. The grey cast iron sustained a load of 11·15 tons per sq. in. for 284 hours and 4·5 tons per sq. in. for 2,600 hours without breaking. The solution discoloured and the bars showed evidence of surface corrosion but there was no evidence of corrosion being accelerated by the stress or suggestion that embrittlement was effected. Austenitic iron failed in a comparatively short time under a load of 9 tons per sq. in., one bar in 0·7 hours and another in 7·7 hours, both from the same charge. Decrease of stress to 5·35 tons per sq. in. increased the time of fracture by almost three times. At a stress of 4·5 tons per sq. in. load was sustained for 2,600 hours without fracture. The tensile strength of Iron A, cast as a 0·5 in. diameter specimen, was 17·2 tons per sq. in. The specimen removed unbroken after 270 hours in hot caustic solution under a stress of 5 tons per sq. in., was subsequently broken at room temperature and showed a tensile strength of 17 tons per sq. in. A specimen which failed after 43 hours at 5·35 tons per sq. in. was broken at room temperature giving a tensile strength of 17·25 tons per sq. in. It would appear that caustic soda is only effective in lowering the time to fracture under stress when material is under the corrosive and temperature influence. Results obtained from the cantilever and beam loadings are also summarised in Table II and are in good agreement with those obtained for tensile loading.

In general, the results obtained from the investigation show that for the corrosive action and temperature considered there is a limiting stress below which the effects of stress-corrosion on austenitic cast iron are either negligible or non-existent. This stress is relatively high in respect of contemplated stresses for cast iron products, and good corrosive resistance of these irons in hot caustic soda can be advantageously utilised as sound engineering practice.

TABLE II.—TIME FOR FRACTURE IN HOURS.

Tensile Loading.

Tensile Strength Tons per sq. in.	Ordinary Cast Iron	Austenitic Cast Iron A	Austenitic Cast Iron B
11·15	284*	—	—
10·0	—	—	1·25
9·0	—	0·7 and 7·7	52
8·0	—	—	2·5 and 6
7·15	—	—	15
6·7	—	3·1	350*
5·35	—	11 and 43	—
5·0	—	270*	—
4·5	2,600*	2,600	2,600*

Beam and Cantilever Loading.

Stress from Beam Formula	Stress from Stress Strain Curve	Austenitic Cast Iron C Simple Beam	Austenitic Cast Iron C Cantilever Beam	Austenitic Cast Iron D Cantilever Beam
49,200	26,300	—	—	0·1
46,800	26,000	—	0·5	—
41,400	24,200	—	1·8	—
39,600	23,700	—	—	0·7
31,100	20,800	—	—	1·2
25,800	18,400	—	12·4	—
24,900	18,000	—	—	5·0
23,200	17,000	8·1	—	—
22,600	16,700	—	—	7·1
22,000	16,400	—	23·6	—
20,400	15,400	—	—	15·5
19,650	14,800	243*	—	—
18,200	13,900	—	—	152
16,370	12,600	—	—	468

* Not Broken.

Microscopical Investigations of Basic Open-Hearth Slags in Reflected Light

By H. Pettersson and S. Eketorp

In order to follow the changes in slag constitution during the melting process, polished specimens of basic open-hearth slag have been examined microscopically.

Samples have been taken from three different normal heats with a basicity $\frac{CaO}{SiO_2 + P_2O_5}$ ranging from 1·16–3·50, from one heat rich in manganese and from one heat rich in phosphorus. The preparation of specimens of slag for microscopic examination has been performed in almost the same way as is used for steel. As etching reagent a solution of 1% nitric acid in water has been used.

By means of a ternary phase diagram based on that of the system CaO-MgO-SiO_2, an attempt has been made to depict the course of solidification and explain the microstructure of the slags.

From *Jernk. Annal.*, 1946, **130**, 664–677.